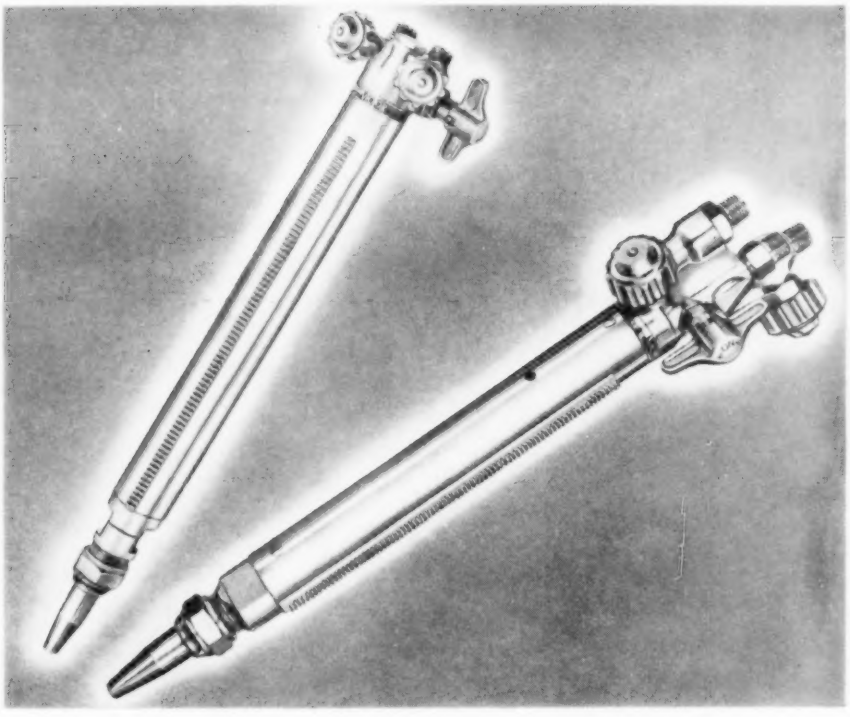
AUGUST 1957

# THE WELDING JOURNAL

## IN THIS ISSUE

Maintaining Workmanship Standards for Quality Welding . . . . . 773
Welded Design for Improved Vibration Control . . . . . 779
An Engineer Looks at the Welding Industry . . . . . 786
Automatic Tungsten-Arc Welding of Aluminum Alloys . . . . . 790
Electrode Control in Pressure-Vessel Plant . . . . . 798
Corrosion Resistance of Stainless-Steel Welds . . . . . 353-s
Welding Metallurgy of Heat- and Corrosion-Resistant Alloys . . . . . 360-s
Ni-Cr-B Brazing of a High-Temperature Alloy . . . . . 366-s
Problems Associated with Welding T-1 Materials . . . . . 373-s
Welding Arcs Using Various Atmospheres and Power Supplies . . . . . 382-s
Design Influence on Residual Stress and Brittle Fracture . . . . . 387-s
Table of Contents . . . . . 769
Editorial . . . . . 771
Index to Advertisers . . . . . 860

OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY



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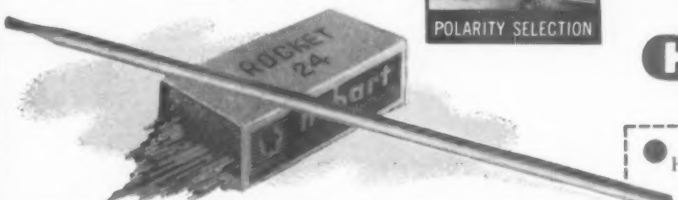


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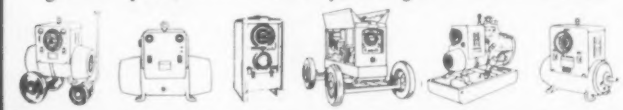
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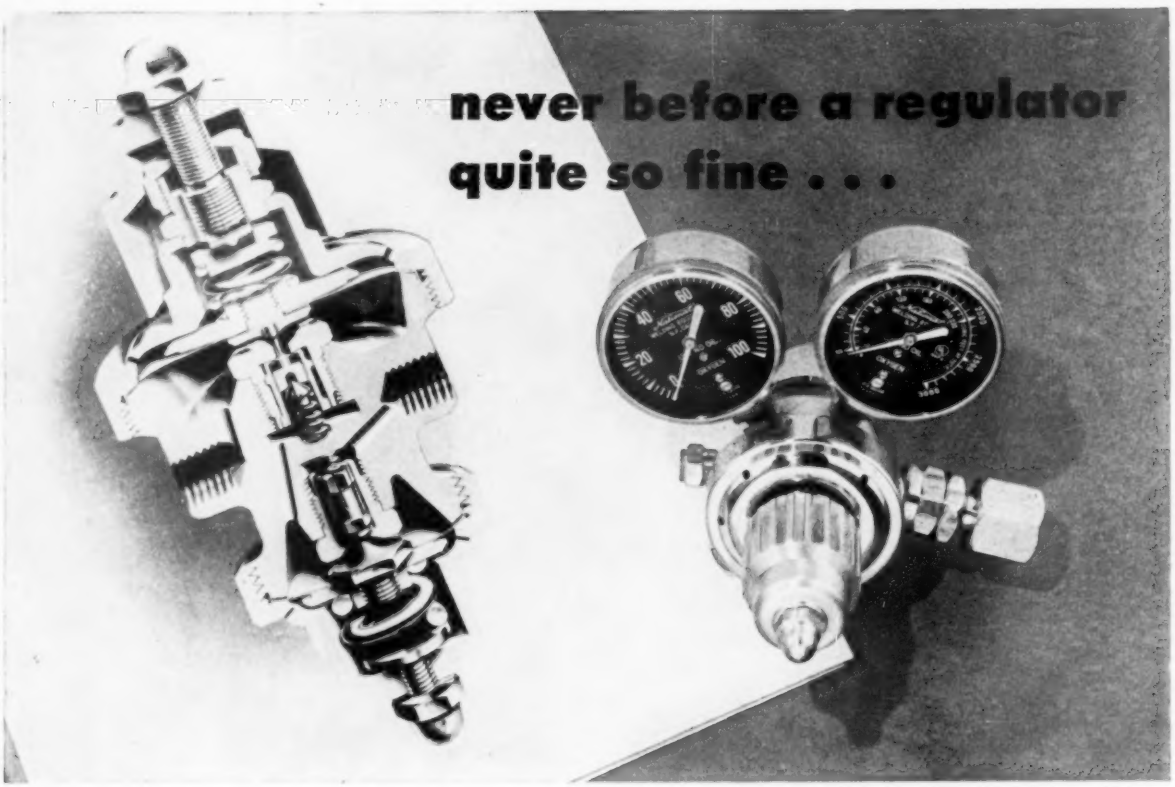


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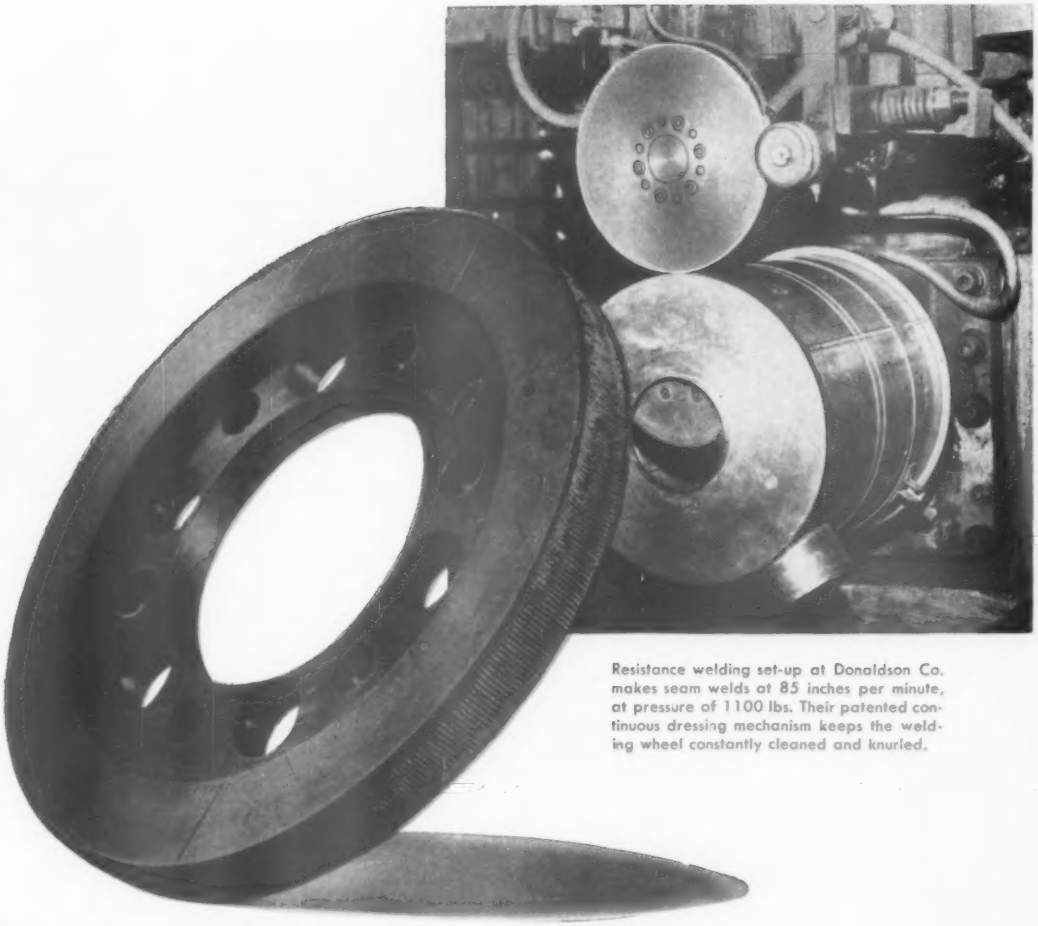

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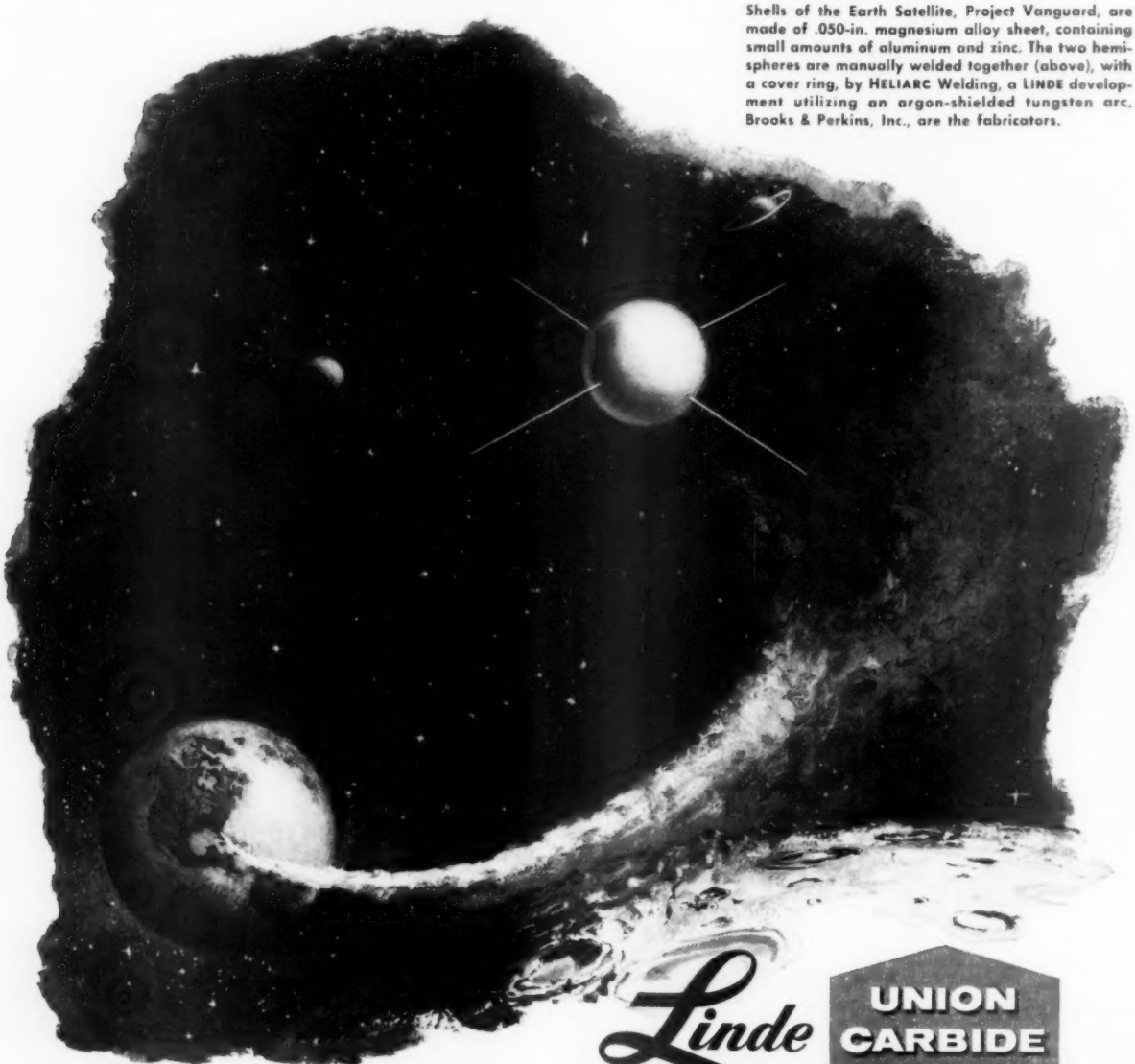

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# THE WELDING JOURNAL

VOLUME 36 • NUMBER 8 • AUGUST 1957

## TECHNICAL PAPERS, ITEMS AND REPORTS


*Editorial—Technical Papers and Your Society, by T. N. Armstrong* ..... 771
*Maintaining Workmanship Standards for Quality Welding, by Howard B. Cary* ..... 773
*A New Concept of Welded Design for Improved Vibration Control, by Omer Blodgett* ..... 779
*An Engineer Looks at the Welding Industry, by Charles Kandel* ..... 786
*Automatic Inert-Gas-Shielded Tungsten-Arc Welding of Aluminum Alloys, by H. D. Mann and R. E. Parkhiser* ..... 790
*Electrode Control in an Alloy Pressure-Vessel Plant, by W. W. Weber* ..... 798


## PRACTICAL WELDER AND DESIGNER


*Gas-Shielded Metal-Arc Spot Welding on Turbine Components, by Lou Ames* ..... 802
*$CO_2$ Process Handles Automatic Welding of Rear-Axle Housings* ..... 803
*Speeding Production of Aluminum Oil Tanks* ..... 804
*Welding—Key to Exposed Steel-Frame Building, by William Brooks* ..... 806
*Tungsten-Arc Welding Licks Aluminum Troubles* ..... 807
*Scrapping for Power, by J. M. Heller* ..... 808
*Triple Life Through Hard Surfacing for Refinery Catalyst Unit Component* ..... 809
*Automatic Welding of Aluminum Fuel Tanks, by J. R. McFarland and Harold Davis* ..... 810
*Tractor Company Welds Galvanized Iron with Aluminum Bronze, by C. V. Kenney* ..... 811
*Standardized Braces and Corners Designed to Improve Appearance of Weldments* ..... 812
*Welding Treasure Islands* ..... 813


## SOCIETY AND RELATED EVENTS


*Society News* ..... 814
*Section News and Events* ..... 819
*New Members* ..... 824
*Current Welding Literature* ..... 826
*Abstracts of Current Patents* ..... 827
*News of the Industry* ..... 830
*Personnel* ..... 836
*Employment Service Bulletin* ..... 840
*New Literature* ..... 843
*New Products* ..... 847
Index to Advertisers ..... 860


## WELDING RESEARCH SUPPLEMENT


*Corrosion Resistance of No. 20 and No. 20Cb Stainless-Steel Welds, by H. C. Campbell, T. J. Moore and S. E. Tyson* ..... 353-s
*Quality Control of Steels for Welded Penstocks, by W. Stauffer and A. Keller* ..... 359-s
*Metallurgy of the Welding of Certain Austenitic Heat- and Corrosion-Resistant Alloys, by A. H. Waterfield and R. P. Culbertson* ..... 360-s
*Ni-Cr-B Brazing of a High-Temperature Alloy, by George Aggen, R. A. Long and E. E. Reynolds* ..... 366-s
*Problems Associated with the Welding of T-1 Material, by Perry C. Arnold* ..... 373-s
*The Electro-Slag Welding Process* ..... 381-s
*Studies of Welding Arcs Using Various Atmospheres and Power Supplies, by T. B. Hazlett and G. M. Gordon* ..... 382-s
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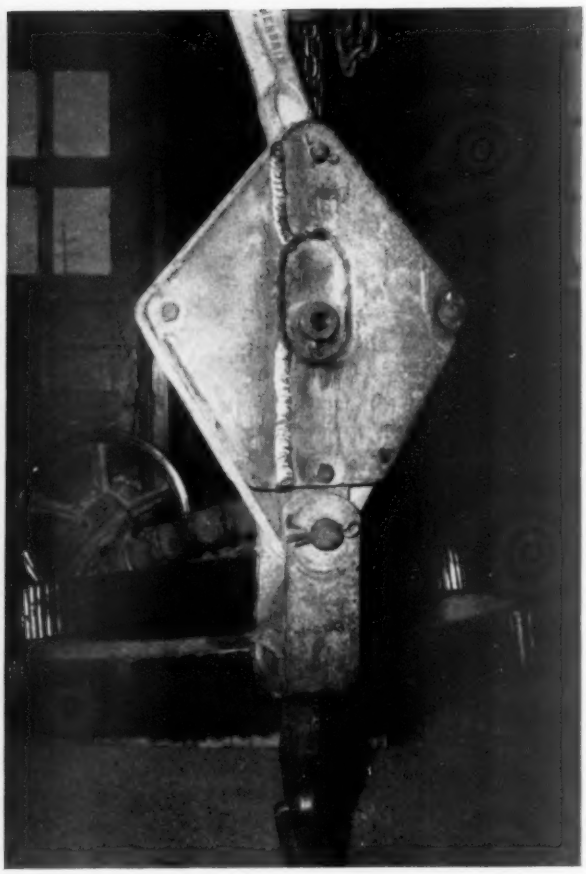

# Cracked cast iron block ...repaired the same day ...with Ni-Rod "55" Electrode

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## TECHNICAL PAPERS AND YOUR SOCIETY

History points out that, periodically, national leaders of unusual vision and ability have arisen that profoundly affected the affairs of their countries. It also shows, however, that it is the character of the individual citizens that ultimately determines a nation's destiny.

This is a truism that has some parallel in many large organizations that are quite remote from the political scene—the character of an organization reflects, in many respects, the collective character of the individuals in it. This applies particularly to a national technical society where the administration changes to some extent from year to year. When the individual members are actively interested in the society's affairs, the organization grows and flourishes; but when the members are complacent and the interest is only casual, the organization languishes.

The usefulness of a national technical society is directly related to the services the members perform for the society. These services include contributions through membership on administration, educational and technical committees, at both the local and national level. They also cover the preparation of high-quality papers, under the society's sponsorship, to provide for adequate dissemination of technical information. The latter is an extremely important function, since one of the best means of judging a society's professional standing is to evaluate the quality and the scope of the technical papers it sponsors and publishes.

Each year our Society solicits papers for presentation at its annual meeting. All papers are carefully reviewed by the Technical Papers Committee. Those which are considered to be of greatest current interest and which contribute most to the technical knowledge are selected for presentation and are recommended for publication in The Welding Journal. Obviously, the number of papers that can be presented at any one meeting is limited. To offset this, all worthwhile papers which cannot be made a part of the program are usually recommended for publication only.

The Journal, with its Research Supplement, enjoys an international reputation as the leading source of information on welding and closely related subjects. An individual whose paper is published therein is not only performing a service to the Society, but he is adding to his professional standing by having his work appear in an outstanding technical magazine.

It cannot be emphasized too strongly that it is essential to have a constant supply of high-quality papers for the American Welding Society to maintain its leading position.

*T. N. Armstrong,*
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Fig. 1 Type 5760 "Mountaineer," 60-cubic-yard power shovel

# MAINTAINING WORKMANSHIP STANDARDS FOR QUALITY WELDING

*Power-shovel weldments produced under specifications and welding-quality controls found to perform extremely well in daily service*

BY HOWARD B. CARY

**INTRODUCTION.** Maintaining workmanship standards for quality welding on any product can only be judged with respect to a quality standard. The standard of quality, to be of any value, must be based on the application of the product. Above all, the standard of quality must be balanced between the economic cost factors and the normal service requirements of the product.

**Howard B. Cary** is associated with the Marion Power Shovel Co., Marion, Ohio.

Presented at the 1956 AWS National Fall Meeting, Cleveland, Ohio, October 8–12.

In many industries and on many products, quality requirements are rigidly controlled by codes and specifications issued by various regulatory bodies. In the power-shovel industry, we are perhaps fortunate in not having specifications imposed on us by outside activities. In view of this, each company in the industry strives for continually higher product quality.

The success of maintaining the delicate balance between quality requirement and economic factors can only be decided in the market place where quality and price determine the company's well being.

At Marion, the picture is indeed complicated, due to the extreme wide range of our products identified as power shovels. To illustrate, on one hand, Fig. 1, the Type 5760 "Mountaineer" with a 60-cu-yd dipper, weighing approximately 5,500,000 lb and costing in excess of $2\frac{1}{2}$ million, and Fig. 2, the Type 35M with a $\frac{3}{4}$-yd dipper weighing approximately 45,500 lb and costing approximately $25,000.

Through many years of shop research and field-performance study, we have arrived at a required standard of welding quality. We also have established welding-quality-control techniques for maintaining the quality requirements. The performance of our machines in the field is a tribute to the success of this program.

## Establishment of Standards

In order to establish a background of welding quality required for our product, we analyzed, and considered for our use, many established codes and specifications. Most of these codes, such as the "AISC Specification for

Fig. 2 Type 35M, $\frac{3}{4}$-yard power shovel

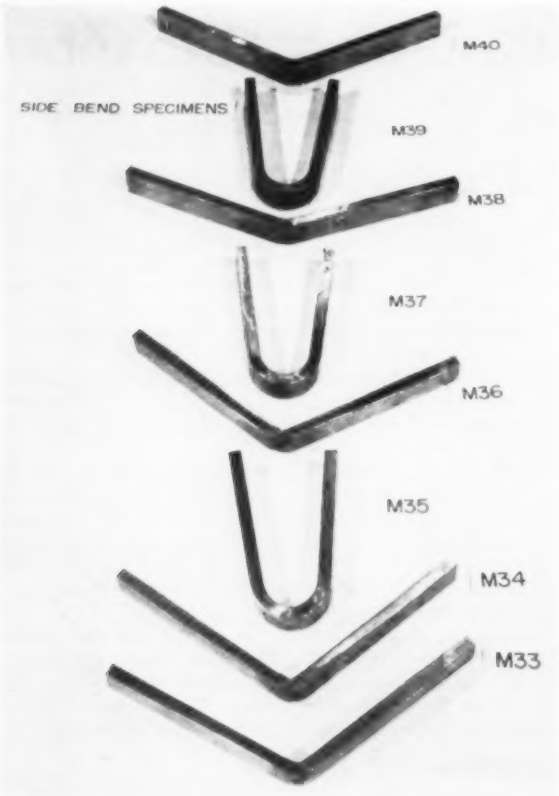


Fig. 3 Bend-test specimens

the Design, Fabrication and Erection of Structural Steel for Buildings," the ASME Section IX "Qualification Standard for Welding Procedures, Welders and Welding Operators," the AWS "Standard Code for Arc and Gas Welding in Building Construction," the AWS "Standard Qualification Procedure," could not be applied in their entirety to our product. However, the various factors considered in these codes were analyzed and developed for our own particular specifications. Almost all codes consider the following:

1. Welding definitions and nomenclature.
2. Welding symbols.
3. Welding process.
4. Material-base metal.
5. Material-filler metal.
6. Allowable stresses.
7. Weldment design.
8. Qualification of joint-design details.
9. Welding-workmanship standards.
10. Qualifications of welding operators.
11. Welding inspection.

Factors 4, 5 and 8, together with welding position and welding technique, are considered as a procedure specification. The various codes were studied and, in as many cases as was possible, we adopted an established standard as written. The various factors were adopted and standardized as follows:

1. *Welding definitions and nomenclature.* We adopted the AWS "Standard Definitions of Welding Terms and Master Chart of Welding Processes" bulletin and reproduced only the more common terms.

*2. Welding symbols.* We adopted the AWS "Standard Welding Symbols" bulletins and reproduced the Master Sheet.

*3. Welding process.* We are involved primarily with only metal-arc welding.

*4. Material-base metal.* Many different base metals are used in our product; however, the rolled-steel products, with which we are primarily interested here, fall into three broad classifications:

(*a*) The mild or low-carbon steels.
(*b*) The low-alloy, 50,000 psi yield strength steels.
(*c*) The high-strength quenched - and - tempered steels.

Specific proprietary steels and steels conforming to certain ASTM specifications were adopted. This will be covered completely under "Procedure Specifications."

*5. Material-filler metal.* We adopted the AMERICAN WELDING SOCIETY specifications for mild-steel arc-welding electrodes and for high-tensile and low-alloy steel arc-welding electrodes; however, only certain of the electrode classification are employed. This also will be covered completely under "Procedure Specifications."

*6. Allowable stresses.* Allowable stress is not within the scope of this paper.

*7. Weldment design.* Weldment design is also beyond the scope of this paper.

*8. Qualification of joint design details.* This, along with base-metal and filler-metal specifications, makes up the procedure specifications. The welding-joint details were designed with the thought in mind to make them the most economical with respect to preparation and to volume of weld metal required. Steels belonging to the mild-steel classification were used to qualify these joint details using mild-steel welding electrodes of AWS E-6012 classification. Many welding tests were performed in the shop and laboratory to qualify the various joints. Each of these test joints were machined and tested to AWS Specifications. Figure 3 shows several bend-test bars of the hundreds produced in order to determine optimum conditions. Meanwhile, an extensive field-service report system was inaugurated in order to correlate field experiences with laboratory results. Figure 4 illustrates the reporting and recording card employed. This is a key sort card printed to our specifications for the data under consideration. Field data, especially low-temperature experiences, quickly revealed the need to revise the electrode types employed. The AWS E-6015 low-hydrogen electrode type was selected and further tests were made. Field reports quickly indicated that this type of electrode should be used for all weldments. Further experimental work was performed on various proprietary low-alloy steels in the 50,000-psi yield strength classification. Three steels were approved by means of laboratory testing for our use. In the high-strength classification, tests were run with quenched-and-tempered steel and various welding procedures and electrodes. The optimum conditions were proved and accepted. The laboratory results, coupled with field experiences, enabled us to select specific base-metal steels, welding-electrode type, and welding-joint-design details. This information was compiled as our welding section of the Engineering Standards. Figure 5 shows the make-up of some of these sheets. Proof that these standards have accomplished their primary purpose is evidenced by the fact that they are now over six years old and have had only minor revisions.

*9. Welding workmanship standards.* Similar standards are covered in most specifications. Particular emphasis is placed on weld sizes and tolerances, surface preparation, undercut, root penetration, repair of defective welds, etc. We took each of the various factors and rewrote them using easy understandable shop terms. These became the workmanship standards of the Welding Section of the Engineering Standards Book.

*10. Qualification of welding operators.* This is a major concern of most specifications. Code qualification of operators is simply an expensive means of assuring that the welding operators are experienced and capable of performing the work required. We have felt that we could assure ourselves that our welding operators and applicants were capable of doing the required work by a simple performance test. This test consists of a vertical fillet weld and a horizontal fillet weld. In both cases, the fillet must be of a prescribed size and

Fig. 4 Field-failure report card

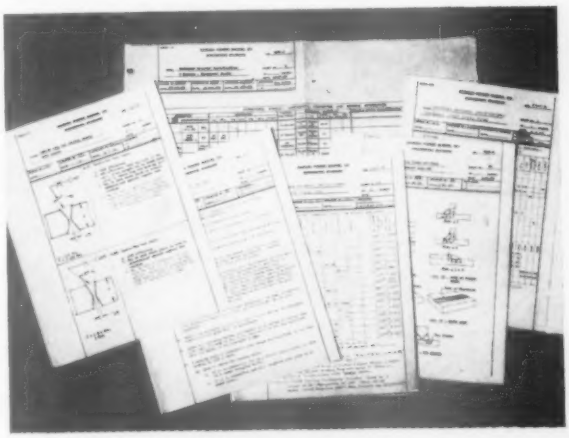

Fig. 5 Typical engineering-standards sheets

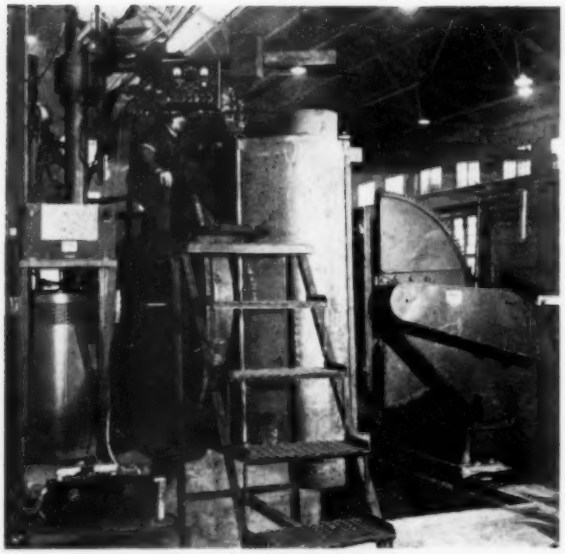

Fig. 6 Automatic welding and positioner

Fig. 7 Welding ring gear on positioner

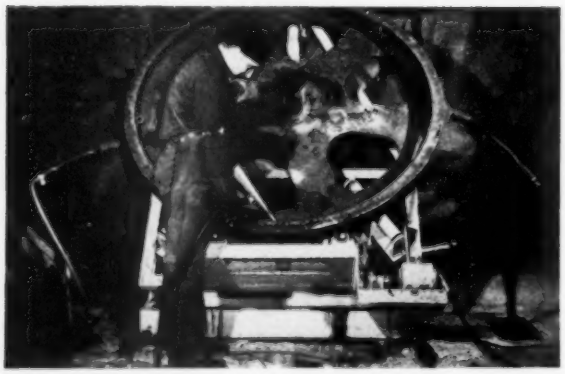

Fig. 8 Semiautomatic welding gear blank

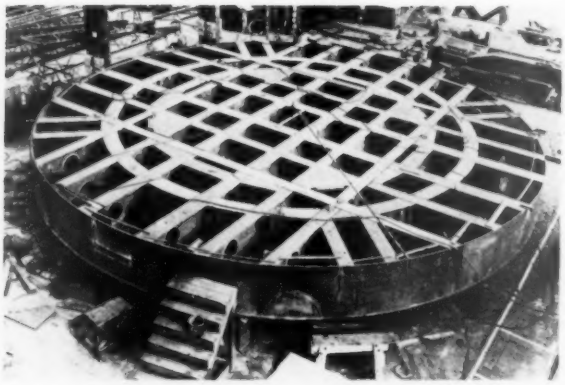

Fig. 9 Walking-drag-line base frame

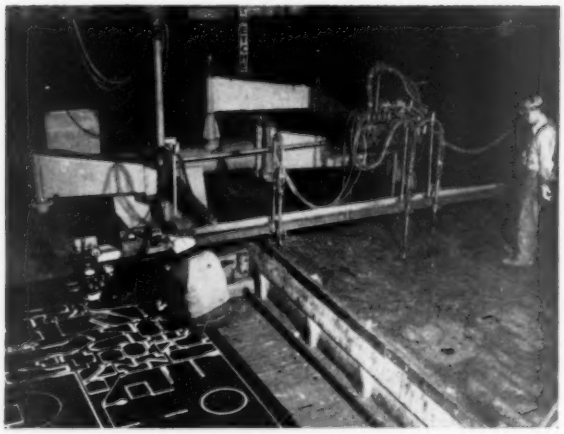

Fig. 10 Chain oxygen cutting with electronic tracer

made with a specific number of passes using electrode type and sizes prescribed. The welds are made with continuous observation. This test, while not conclusive, indicates whether the operator has sufficient training and experience to perform the normal work expected. This test is used for welding operator applicants as well as for those completing our "on-the-job" training program.

*11. Welding inspection.* Most codes define the jurisdiction of the welding inspectors. We specify that any weldment may be taken and subjected to 100% inspection to insure compliance with welding specifications, procedures, and workmanship standards. We also specify that continuous spot checking will be made during all phases of manufacturing. Provisions are made for immediate correction of any errors found.

## Special Welding Procedures

Basic engineering standards cannot be expected to cover the many requirements for manufacturing our varied products. As a result, we have written special information sheets to cover specific subjects.

Sheets have been written giving information for repeat type applications where the same data are required many, many times. For example, sheets were written on the measurements of fillet welds and the proper use of the fillet-weld gage. Sheets were also

written giving the exact specifications for automatic welding of joints. These sheets show settings for current, voltage, speed of travel, electrode size, etc., for each of our standardized joint details. This information has been carefully worked out by making many tests and shop runs. Figure 6 shows the application of automatic welding on the lower frame of a power shovel.

Welding-procedure sheets are also written when special instructions must be given to a particular group of men for a particular occupation. For example, instruction sheets were issued outlining our material identification system. This, while not a welding instruction, is so closely allied to welding that it was felt necessary that it be published. Another sheet outlining responsibilities for setup personnel toward marking weld sizes on the joints of the weldment was published. Other sheets covered such items as operating procedures for specialized machines, etc.

Procedures were also required to establish new or unusual techniques for accomplishing special jobs. Figure 7 shows a ring gear being welded to the lower frame of a shovel. This particular job, due to joint geometry and steel analysis involved, had been particularly troublesome until special techniques were worked out. Once established and formalized on a written procedure, the job was much simplified. Another job of similar nature is shown by Fig. 8. In this case, a gear blank is being welded. The ring is of high-carbon steel, welded to a mild-steel web. Welding procedures for semiautomatic welding gear blanks were worked out and then established as a permanent procedure.

In addition to the above type of instruction sheets, we have issued many, many procedures giving specific instructions for building large or complex weldments. These sheets are used to augment blueprints and to give a step by step instruction for properly building the weldments in question. Figure 9 shows the base frame or tub for a large walking-dragline type machine. This weldment must be perfectly true and flat and this can only be accomplished by following a carefully worked-out procedure. There are many, many types of weldments in our large machines that require written procedures.

Written welding procedures have proved invaluable in maintaining quality, since the best technique is established and then recorded. This allows us to consistently build the weldment the same way each time it is produced. Information is made available in a clear understandable manner and recorded so that it can be referred to at a later date by those concerned.

## Organizing for Quality Welding

In order to insure quality welding, management is responsible to provide the following:

1. A basis or specification outlining the degree of quality required.
2. Equipment and facilities conducive to quality workmanship.
3. Quality materials with which to work.
4. Experienced workmen.
5. Responsible experienced supervision.
6. Inspection to guarantee compliance.

1. The basis or specification in the absence of a code has been well covered.

2. The best available equipment and facilities should be employed. This does not apply only to welding machines and accessories, but to jigging equipment, face plates, material handling equipment, and preparation facilities. Quality welding requires quality setup which in turn requires quality material preparation. Figure 10 shows our oxygen-cutting equipment using an electronic tracer on a chain-type template. This setup produces extremely accurate parts necessary for quality welding.

3. The material section of the Engineering Standards specify quality materials. Receiving inspection personnel insists that incoming materials meet the specifications.

4. The experience of welding operators is checked by means of the aforementioned performance test. This is only a guide to the operator's ability. Continuous surveillance and supervision is maintained on welding operators. Each operator is given the responsibility to make each bead a quality weld. Good relationship is essential between the operators and supervision as each and every weld cannot be inspected. Welding operators must be kept advised of any changes in procedures and standards.

5. Experienced and responsible supervisors are an absolute necessity. Supervisors must be experienced in all of the welding operations, and also must have field experience with the product. Above all, they must be good supervisors. Supervisors must be kept informed on all matters pertaining to their departments and responsibilities.

6. Experienced inspection personnel must be responsible to higher management and in no way responsible to Welding Department management. All comments regarding welding operators and supervisors must also apply to welding inspectors.

## Maintaining Quality Welding

The responsibility for producing quality welds rests upon the welding operators. They must accept this responsibility. The welding supervisors must accept the responsibility of the operators and for producing quality weldments. The welding inspectors must guarantee that quality standards are maintained. The welding standards, and especially the workmanship standards, are the basis for welding operator, welding supervisor and welding inspector relationships.

The guarantee for quality welding is eternal vigilance. Welding supervisors and inspectors are continually alert for evidence of substandard workmanship. Visual inspection is perhaps most greatly used. This includes inspection of joint preparation at setup prior to welding and visually watching the weld being made as well as checking weld size and observing the final passes.

We have adopted many techniques for assuring qual-

ity welds. For example, each and every major weldment has an identification and inspection plate welded to it. By means of metal stamps, the part number, order number and inspection symbols are imprinted on this plate. This serves as a control of quality since, by means of this information, the entire history of the weldment can be traced through the welding shop.

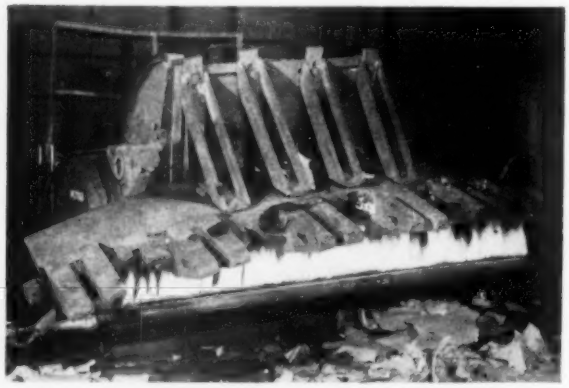

Fig. 11 Dipper-lip weldment being preheated

Fig. 12 Root bead magnetic-particle test procedure

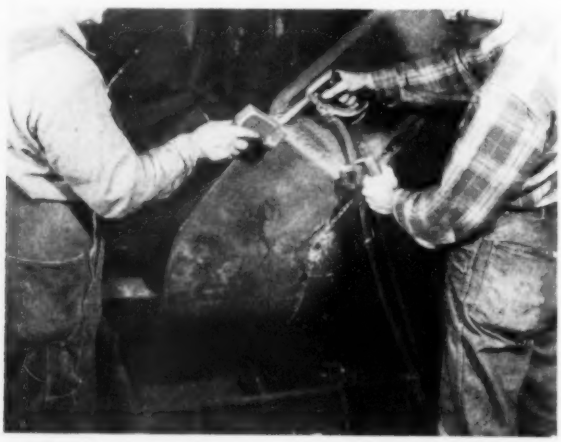

Fig. 13 Intermediate magnetic-particle test procedure

Another quality-control technique that we have adopted is in connection with weldments requiring preheat. Figure 11 shows a lip assembly for a 45-cu-yd dipper. The $6^1/_2$-in. thick lip plate is of quenched-and-tempered T-1 steel and the tooth bases being welded to it are of AISI 4140 steel, also quenched and tempered. Fairly high preheat is required and this preheat must be maintained until the welds are completed. In order to insure that preheat is maintained, we utilize a preheat log sheet. This sheet shows the part number and order number. Space is provided to show when the job was started, the department or area where the job is worked and, above all, the specified temperature that must be maintained during welding. Entries are then made, each half hour by the welding supervisor throughout the duration of the job, showing the temperature as measured at specified points on the weldment. Temperature is measured by means of temperature indicators in the stick form. This log sheet is verified by means of spot checks made by welding inspectors.

Another inspector's tool that we employ to a great degree is the magnetic-particle inspection process. Many weld joints in our weldments are located at critical points and are required to be perfect. Experience indicates the location of these types of joints. In such cases, the designation "100%" is shown in the tail of the welding symbol specifying the joint. This indicates to welding personnel that, on root pass and on final pass, magnetic particle inspection is required. Figure 12 shows the root pass of a weld joint joining the lip plate to the dipper proper being so inspected. Figure 13 shows intermediate magnetic-particle inspection when the same joint is approximately 25% completed. Any defects found at either of these stages are removed and repairs are made which are again inspected by the magnetic-particle method. Several intermediate-like inspections will be made in the course of completing a critical weld joint, the number depending on the thickness of the joint. Magnetic-particle inspection of the completed weld is the final check to satisfy the 100% requirement.

Final-pass magnetic-particle inspection is also employed on many other weld joints of a less critical nature.

A visual inspection is made of all welds on each weldment after stress relieving and gritblasting. This check reveals any undercuts, overlaps, roughness, nicks and otherwise objectionable factors. Any such defects found are immediately repaired before further processing.

## Conclusion

We have attempted to show the welding-quality controls employed in the company. We feel that the weldments in a power shovel are subjected to extremely abusive service. The weldments produced under the specifications and controls outlined herein are standing up in daily service in thousands of operations throughout the world. This is a tribute to the soundness and success of our welding-quality control program.

# A NEW CONCEPT OF WELDED DESIGN FOR IMPROVED VIBRATION CONTROL

*Paper discusses some new ideas about vibration and its control through the use of welded steel which have come out of recent research*

BY OMER BLODGETT

The control of vibration is a design problem in machinery of many different types. In the past, this problem, to some extent, has discouraged designers in the use of weldments. It has been felt that the damping capacity of cast iron is an advantage in controlling vibration. Contrary to popular belief, efficiently designed welded steel has superior properties for coping with vibration problems found in many types of machine tools.

In recent years, there has been considerable research among machinery builders on the subject of vibration. Grinding machine manufacturers and printing equipment manufacturers, in particular, have been concerned, since improved control of vibration results in increased operating speeds for grinders and printing presses. New ideas about vibration and its control through the use of welded steel have come out of this recent research. This paper will discuss some of these ideas.

## Contributing Forces for Vibration

All members have a certain *natural* frequency. When struck once with an object, they will vibrate naturally at a given frequency.

A member also can be *forced* to vibrate at any frequency by striking it repeatedly. This is called the forced frequency.

Whenever forced frequency equals natural frequency, the member becomes resonant and the amplitude of the vibration quickly builds up to a very high value, usually with disastrous results. A vibration becomes a problem only when its amplitude or height of vibration becomes excessive.

The damping property of a material is its ability to absorb the energy of the vibrating force. This is due, for the most part, to internal friction of the material.

Figure 1 shows the relative amplitude of vibration for a simple member when subjected to increased frequency of vibration. At resonant frequency, where the ratio of forced frequency to natural frequency is equal to 1, the amplitude is greatly increased. Theoretically, if there were no damping, the amplitude of vibration at this point would be infinitely high. For materials with greater damping capacity, the amplitude of vibration in the resonant frequency range is lower.

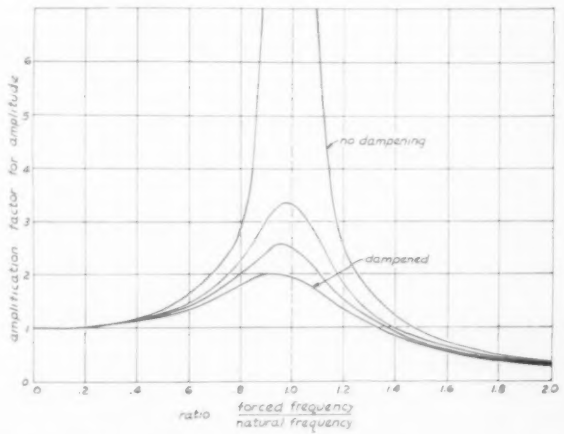


**Fig. 1 Effect of damping capacity on the amplitude of vibration. Damping reduces amplitude in the resonant frequency range**

## Vibration Problems

Vibration problems may be summarized with the following facts:

1. Excessive amplitude of vibration is the cause of the problem.
2. The amplitude of vibration becomes excessive in the resonant or critical frequency range.
3. Resonant or critical frequency is reached when the forced vibration equals the natural frequency of the member.
4. Damping capacity limits amplitude in the resonant range.

This means that the solution to a vibration problem would mean either:

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Presented at the 1957 AWS National Spring Meeting, Philadelphia, Pa., April 8–12.

$$f = K\sqrt{\frac{EI}{AL^4}}$$

where $L$ = length of member
$A$ = area of cross section of member
$E$ = modulus of elasticity of material
$I$ = moment of inertia of section

Fig. 2 Formula for natural frequency of a simple beam

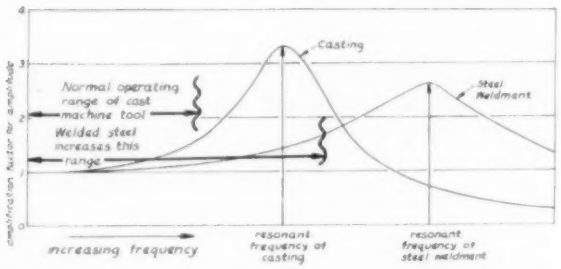


Fig. 3 Steel increases the efficient operating range of a machine

1. Changing the forced frequency, preferably to a lower frequency. This usually means a change in motor or operating speed.
2. Changing the natural frequency of the member, preferably to a higher frequency.
3. Increase damping capacity through efficient steel design.

## Natural Frequency of Member

In starting up a machine from zero speed, it is better if the machine does not have to pass through its critical speed or frequency. This means, if the natural frequency of the member is to be changed, it would be better to move it up to a still higher value.

In order to make any change in the natural frequency of a member, it would be well to study the factors involved in the vibration of a simple beam. This simple beam is similar, to some extent, to a complicated machine part or member; at least, what is learned from this can be applied to larger and more complicated members (see Fig. 2).

From this basic equation for a simple vibrating member, it is seen that the natural frequency can be increased by:

1. Increasing the moment of inertia, $I$, of the member.
2. Using a material having a higher modulus of elasticity, $E$.
3. Reducing the cross-sectional area, $A$, of the member (similar to weight).
4. Reducing the unsupported length, $L$, of the member.

Whenever a steel weldment is designed from an existing gray-iron casting, three things happen:

1. Results in a higher modulus of elasticity, $E$, $2^1/_2$ times as much as gray iron.
2. Requires less moment of inertia, $I$, for the same stiffness, 40% of that for gray iron.
3. Requires less area, $A$, for the same stiffness, 40% of that for gray iron.

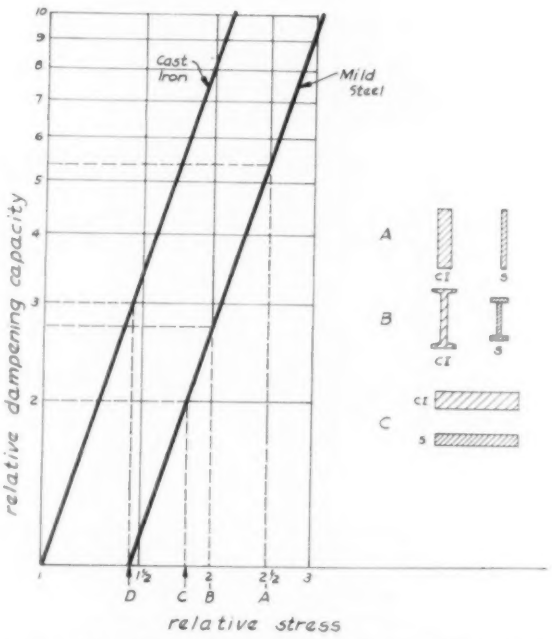


Fig. 4 Equivalent designs in steel for cast-iron sections, for the same load, are always stressed higher. Because of this higher stress, the relative damping capacity of steel will increase above that of cast iron

The results of these three changes upon the natural frequency of the member is:

$$f = k\sqrt{\frac{EI}{AL^4}} = \sqrt{\frac{(2.5)(0.40)}{(0.40)}} = 1.58$$

The natural frequency of the equivalent steel member will be 1.58 times the natural frequency of the gray iron member; in other words, the natural frequency has been increased 58%. Simply changing from gray-iron castings to steel weldments has given us 58% greater operating range. This is illustrated in Fig. 3.

In addition to this, it is very simple to add stiffeners to steel weldments, so that the unsupported length of panels or members is greatly reduced. Notice that the addition of a single stiffener, which cuts the unsupported length to half, will increase the natural frequency of the panel four times. This is a very easy method to get the natural frequency far away from the operating frequency.

## Damping Capacity

It has been argued for some time that gray iron has superior damping capacity over steel. This is true only if both are stressed the same amount. This is shown in Fig. 4. When both materials are stressed the same amount (see vertical line, $D$) gray iron has about three times the damping capacity of steel. However, in an efficient redesign of a casting to a steel weldment, where the redesign is based upon equal

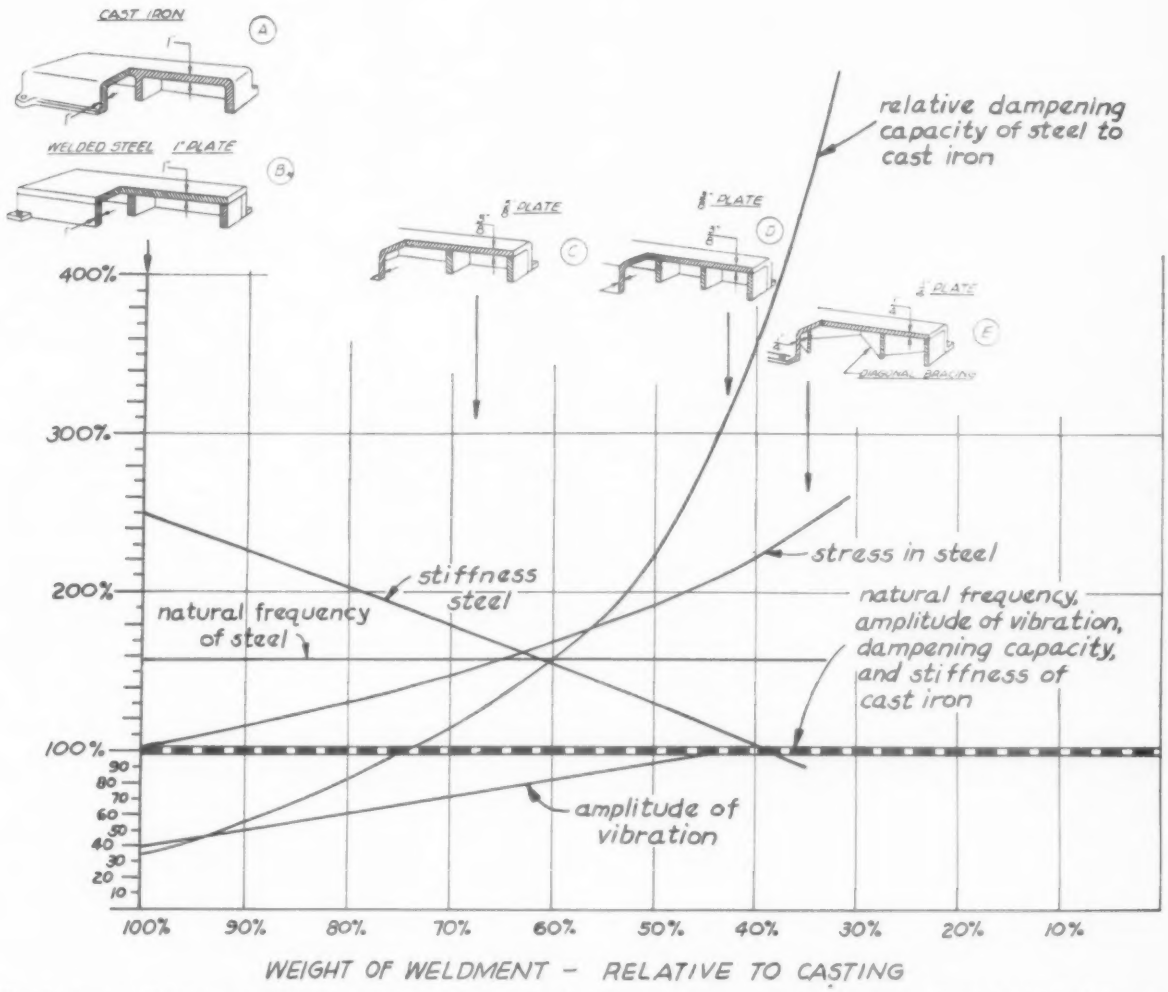


Fig. 5 Curves illustrate what happens to vibration in a steel weldment as the weight is reduced to where the design becomes more efficient

stiffness, the steel member is always stressed more than the corresponding casting. Steel, having a higher modulus of elasticity, requires less moment of inertia for the same stiffness and, as a result, has a lower section modulus. Therefore, for the same load, the steel member will have a corresponding higher stress. Because of its higher stress, its relative damping capacity will increase.

It can be shown in the case of a vertical member, such as the side of a base (see *A* of the same figure) in which the depth remains unchanged, that the steel is stressed $2^1/_2$ times that of the corresponding casting and will have a damping capacity 5.3 times that of the casting. In the case of a similar section (see *B* of the same figure) the stress is two times that of the corresponding casting and results in a damping capacity 2.7 times the casting. Even in the case of a flat panel in which the width remains constant (see *C* of the same figure) the stress in the steel is 1.84 times the casting and results in a damping capacity two times that of the casting.

These are not difficult steel sections to make nor unusual conditions; they represent every-day, normal steel redesigns from cast construction having equal stiffness.

## Vibration Properties of Steel Weldments

The history of a particular redesign of a gray-iron cast base to subsequent designs in welded steel is shown in Fig. 5.

At the extreme left-hand axis is the original cast base along with the first steel redesign, *B*, in which the same section was used. The horizontal axis represents the weight of the steel designs expressed as a percentage of the original cast design. The various curves show what happens to the steel weldments as far as vibration is concerned when the design becomes more efficient as the weight is reduced.

Although some designers have made their first steel redesign an exact copy of the casting, it is obvious from this figure that this is not the best design. Consulting steel design, *B*, notice the following:

1. Even though it is to replace a casting, it is, nevertheless, $2^1/_2$ times as rigid as it should be.

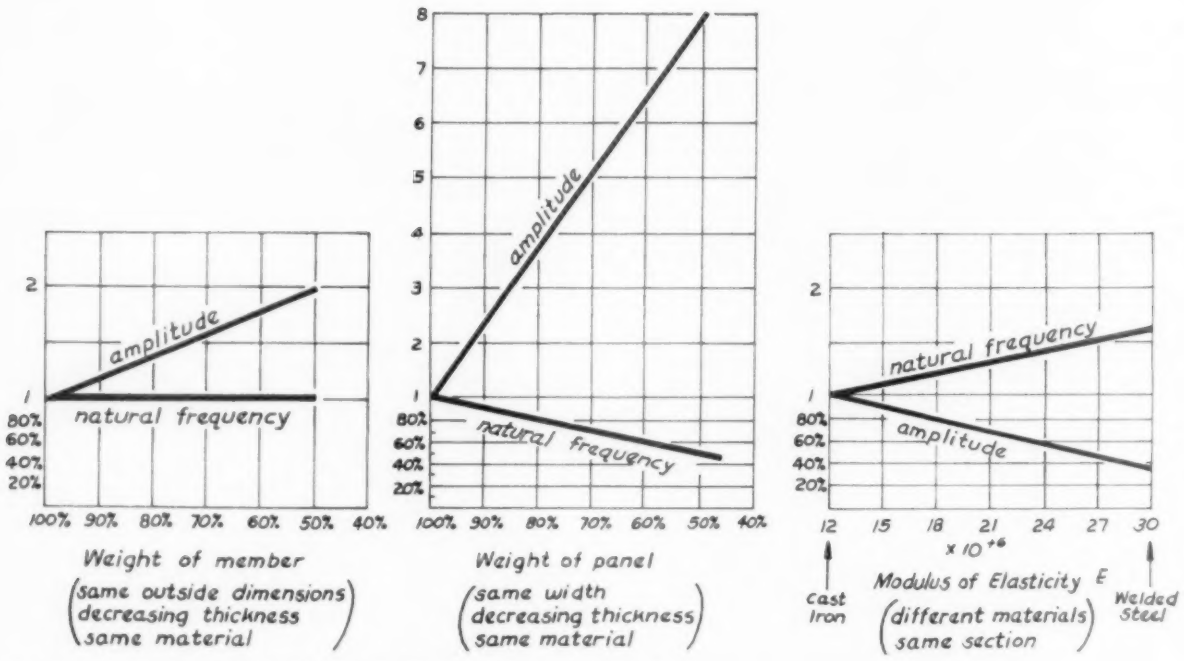


Fig. 6 The effect of weight reduction and material change on vibration

2. Because it has the same section and still carries the same load, it is stressed the same as the casting.

3. Its relative damping capacity is about $\frac{1}{3}$ that of the casting.

4. Its natural frequency is 1.58 times that of the casting.

5. Its amplitude of vibration is only 40% that of the casting.

As long as this steel-base design, *B*, is operated below its much higher natural frequency, there should be no vibration problem. If, for some reason, it should operate near its resonant frequency, its lower damping capacity might be a disadvantage.

No steel redesign should be made upon the basis of duplicating the cast section; instead the steel should be reduced so that equal stiffness is obtained. This has been done progressively in steel designs *C*, *D* and, finally, *E*.

What are the results of this equivalent steel design, *E*?

1. The weight of the steel weldment is about 40% that of the casting and will result in savings in material, as well as cost.

2. Its stiffness has been reduced to that of the casting.

3. It is stressed 2.2 times that of the casting. This is conservative, since steel is four times as strong.

4. This higher stress results in a damping capacity about 3.3 times that of the casting.

5. The natural frequency is 1.58 times that of the casting, resulting in a much wider and safer operating range.

6. The amplitude of vibration will not exceed that of the casting.

## Effect of Weight on Vibration

Normally the over-all dimensions of a member must remain unchanged in any redesign. If the weight is to be reduced, this is usually accomplished by means of thinner sections. In general, if the shape and outside dimensions remain unchanged, then the moment of inertia of this section will vary as the thickness, or as the weight of the member. A reduction in weight would, therefore, mean a corresponding reduction in the moment of inertia of the section.

The effect of reducing the weight of a member is shown in Fig. 6. Although the natural frequency of the member would remain unchanged, the resulting amplitude of vibration would increase with decreased weight. For example, a reduction in weight of 50% would result in double the amplitude of vibration (Fig. 6, left).

Reducing the weight of a flat panel would cause a still greater vibration problem (see Fig. 6, center). The natural frequency is lowered and the amplitude is greatly increased. Reduced natural frequency means that the member will have a much narrower range to operate in and that there will be a greater possibility of it being operated at resonant frequency. At resonant frequency, the amplitude of vibration would be abnormally high and would prevent the machine from having any useful purpose.

It is important to emphasize that this is caused by the reduction in moment of inertia and not directly by the reduction in weight. It is possible to change from a heavy cast member to a lighter welded-steel member and have less amplitude of vibration and higher natural frequency.

If welded steel were to be used in place of the casting,

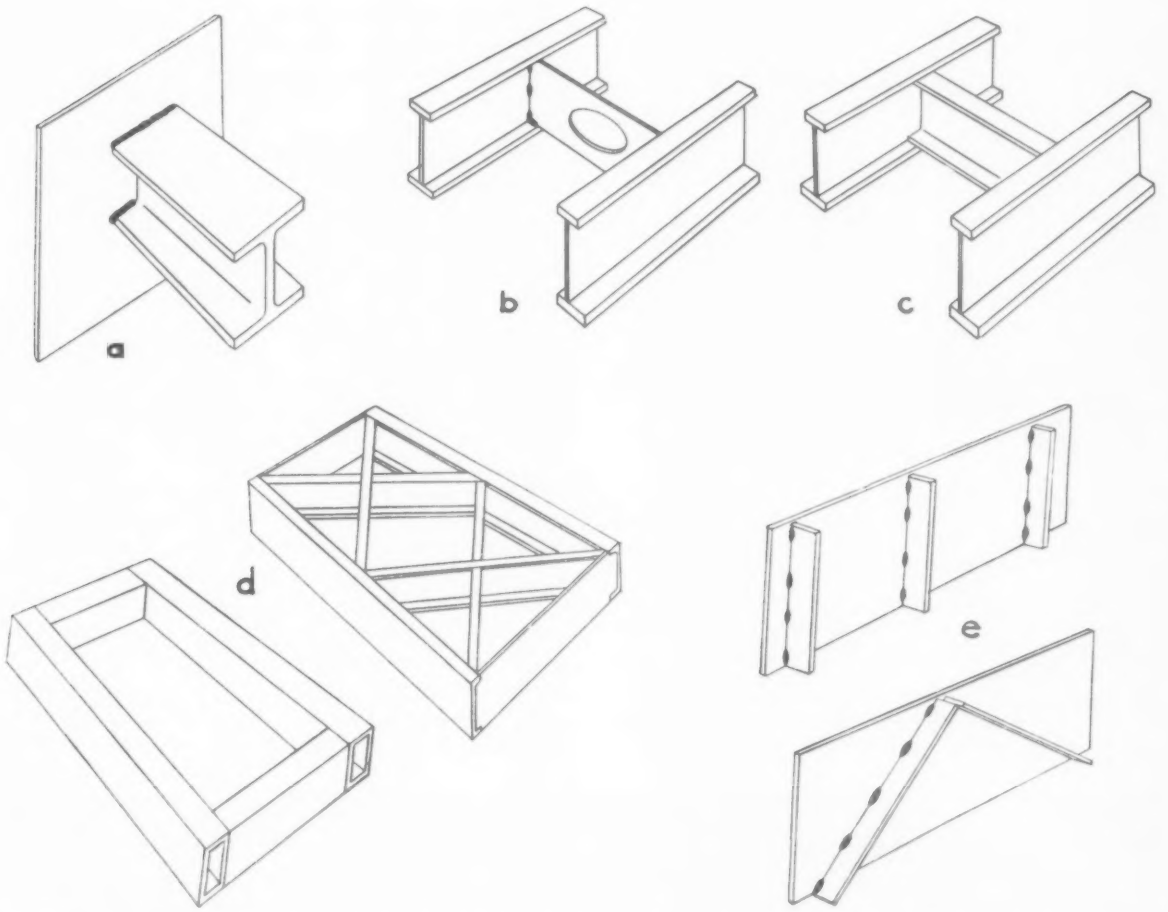


Fig. 7 Design ideas for vibration control: (a) welding ends of a member reduces amplitude by 80% over simply-supported member; (b) punching holes in a stiffening panel reduces areas and increases natural frequency; (c) flange longer panels to increase stiffness and increase frequency; (d) closed sections or diagonal bracing increases torsional resistance (R) which increases frequency and reduces angle of vibration; (e) small tack-welded stiffeners increase natural frequency and, when placed at 45 deg, add resistance to twist

in other words, a different material with a greater modulus of elasticity ($E_{cast}$ = 12,000,000 psi to $E_{steel}$ = 30,000,000 psi), then, for the same section, the natural frequency will be higher (1.58 times) and the amplitude of vibration will be lower (40%). This is shown in Fig. 6, right.

If the redesign from the casting to welded steel is made for equivalent stiffness or rigidity, as is usually done in machine tools, the increased modulus of elasticity would allow a corresponding decrease in the required moment of inertia. This would reduce the weight to 40% without any increase in amplitude of vibration over that of the casting.

## Summary

Experience has proved that efficient steel weldments weigh less than corresponding castings and this reduced weight will not create vibration problems. On the contrary, steel has superior properties for designing where vibration is an important consideration:

1. Steel can have a damping capacity equal to or greater than cast iron because an equivalent steel design under the same load is stressed higher.

2. The reduced section of the steel equivalent design has a greater modulus of elasticity; hence, reduced amplitude of vibration and, therefore, higher natural frequency. This means a greater operating range.

3. The design flexibility of welded steel makes it easy to shorten unsupported lengths and make other changes that increase natural frequency and decrease amplitude.

## Examples of Welded Design

Various design ideas for minimizing vibration are illustrated in Figs. 7 and 8. Suggestions are also given for reducing noise. Figures 9, 10 and 11 illustrate machines that have been designed to improve operating characteristics by eliminating vibration.

The welded printing press illustrated in Fig. 9 is used in printing color work for a popular magazine with a

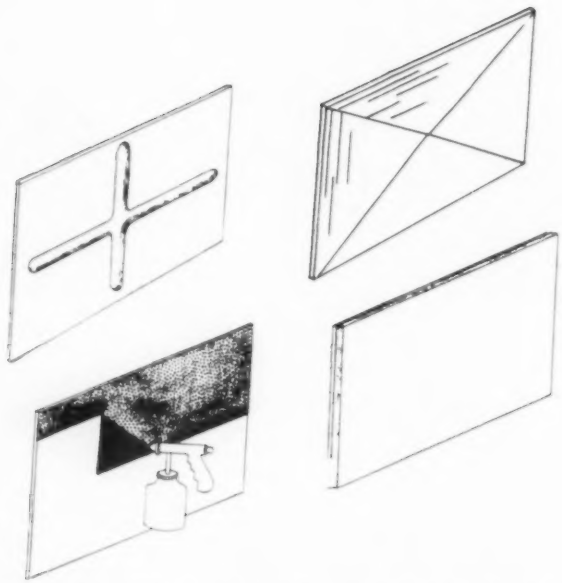

Fig. 8 The pitch of noise resulting from vibration depends on the frequency and the volume depends on the amplitude. A noise problem is solved as a vibration problem: changing the frequency through stiffeners, stampings, breaking into smaller panels to reduce unsupported length; sprayed-on coatings or cemented fiber materials will increase damping of very thin sections

circulation over one million. Color register and high speed are important. The welded press has resulted in substantial reductions in operating cost through its improved rigidity and, hence, better register at higher speeds.

In the design of a welded-steel bed for a new internal grinding machine, Fig. 10, the engineers in charge developed a high degree of functional rigidity, while making a significant weight reduction. The machine is used for internal grinding of inner rings for large ball bearing assemblies. The new welded-steel bed weighs only 1788 lb, against 1829 lb for a cast-iron bed on the previous design. However, the swing of the new machine was increased from 9 to 12 in., so, in view of the higher capacity, a fairer comparison is on a unit weight basis, the figures being 149 lb against 203 lb, or a 26% saving. The cost of the welded bed was also substantially less than the former cast-iron design.

Comparative vibration tests on the old and new versions of the grinder were made by running production lots of bearing rings. The new design reduced grinding time from 13 to 8 sec; lowered size variation from 0.00040 to 0.00015 in. and improved surface finish from 21 to 10 microinches rms.

A leading grinder company, in its 10-year experience with welded design of precision grinding machines, has demonstrated convincingly the advantages of steel in

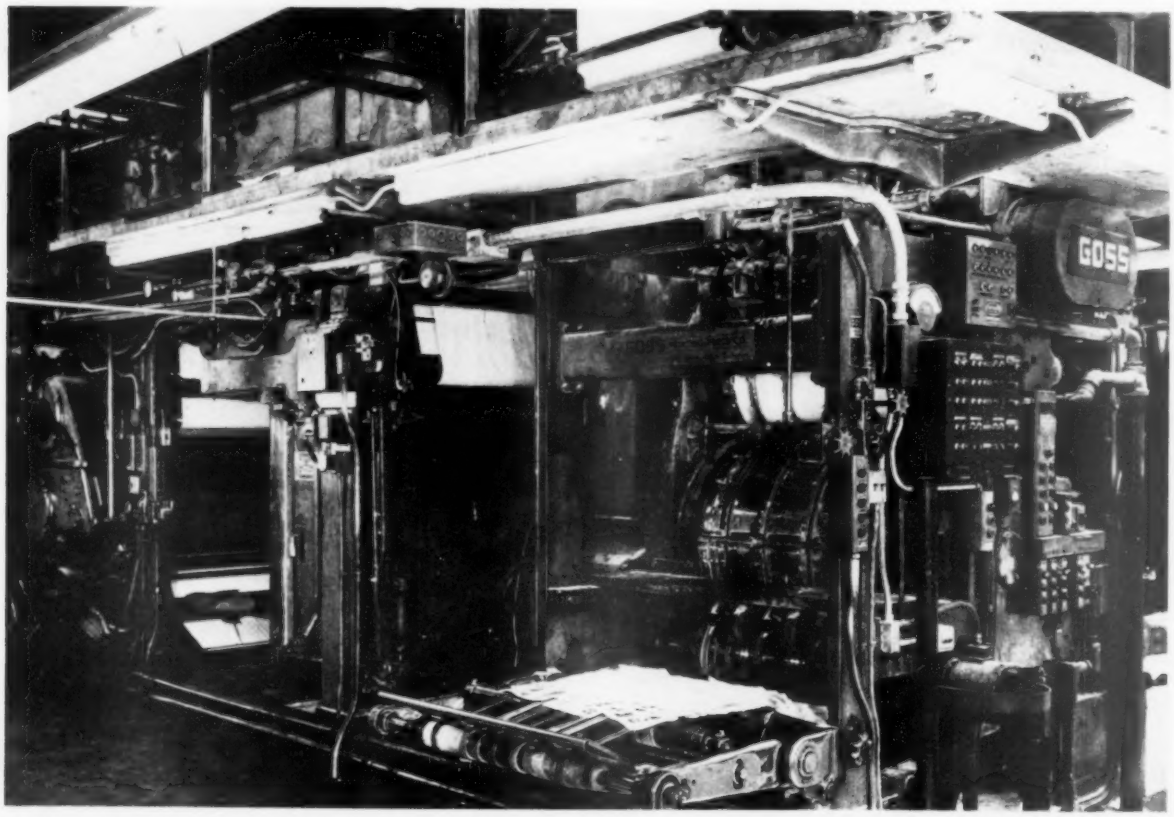


Fig. 9 This 75-ft welded-steel printing press, built by the Goss Printing Press Co., runs at 11,500 impressions per hour, compared to the 4000 by the press it replaced. Register on color work is better at higher speeds because rigidity has reduced vibration

vibration control. Figure 11 shows a rotary surface grinder which has a weldment base and column. It is designed for maximum rigidity with minimum weight.

This company's engineering department recently released comments on their selection of weldments which summarizes some of the foregoing analysis:

"The original grinder was built in our plant in 1947. It has a fabricated base and has been in continuous service during the intervening nine years. None of the wearing surfaces, which are part of the fabrication, have ever had to be touched in all that time. Some 135 machines with fabricated bases have been delivered to date. After numerous experiments, we have found that a fabricated base can be made just as strong and just as free from resonance as any cast-iron base. Also, it is sometimes difficult to rib a cast-iron base because of resulting blind pockets which can cause blowholes or spongy material because of trapped gas, and from which dirt can never be cleaned properly. No such difficulties have been encountered, when a base has been of welded steel. Ribs can be placed quite close together, exactly where they are required, without any damage whatever to the structure of the metal.

"On the question of vibration, or resonance, the matter has been studied closely by us . . . . Every machine that is sent out of this shop, whether its base be a weldment or east iron, is analyzed thoroughly according to a standard inspection pattern with a vibration analyzer. This instrument enables us to probe and detect vibration in any part of the machine and also to detect and correct any source of vibration in the machine . . . .

"We realize that cast iron has been the usual material for bases for more years than most people have been around the machine tool industry. This fact, however, does not mean that cast-iron bases must be better. In our opinion, it simply means that, first, pouring molten iron is, perhaps, the simplest and most obvious way of producing intricate shapes with hollow interiors and, second, that, in the days when this method became standard practice, the science of welding did not exist."

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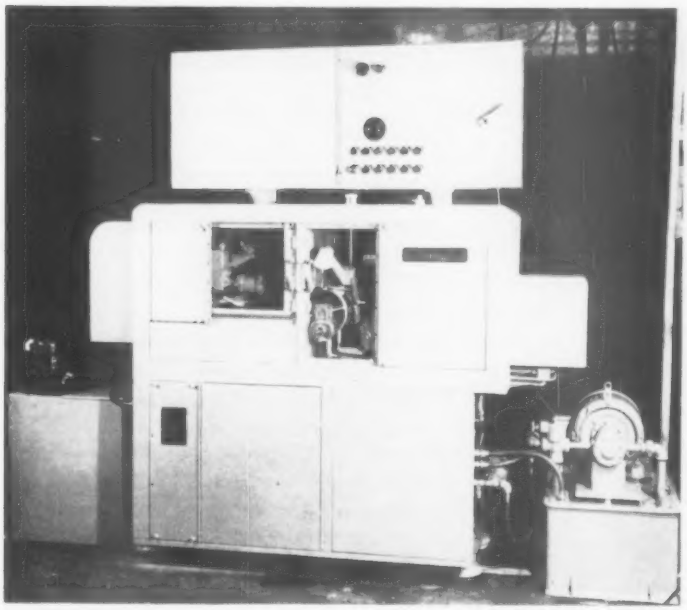


Fig. 10 This internal grinder made by Bryant Chucking Grinder Co. has a welded-steel bed. The design develops a high degree of functional rigidity while making important weight reduction. Higher operating speeds within closer tolerances

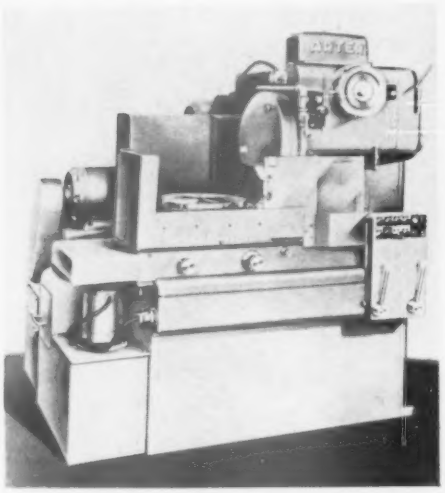


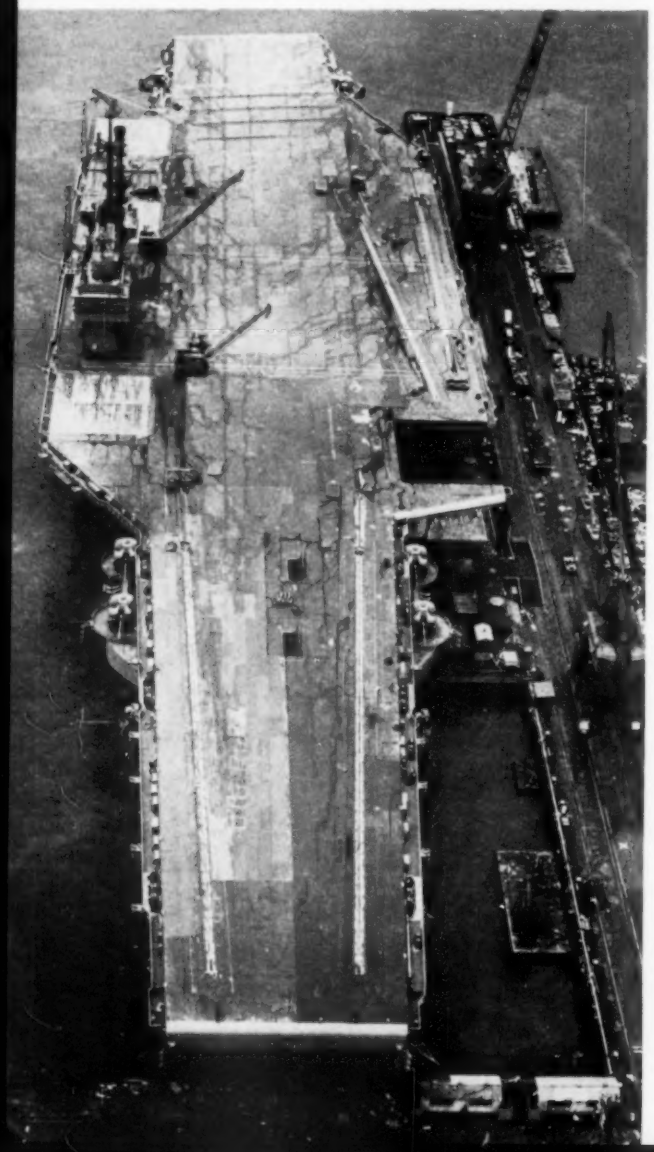
Fig. 11 The Arter Grinder Co. has been using welded bases for over 10 yr. Through a program of close testing and checking with instruments, company engineers are assured that they achieve better vibration control with welded steel

# AN ENGINEER LOOKS AT THE WELDING INDUSTRY

BY CHARLES KANDEL

*The welding industry offers a distinct challenge to a young engineer's creative ability, imagination and resourcefulness, the author points out*

Fig. 1 Aerial view of U.S.S. "Forrestal" while in process of being completed. Some 2,000,000 lb of weld metal—the equivalent of 2400 miles of $^1/_4$-in. welding—were used in the fabrication of this aircraft carrier



**INTRODUCTION.** The welding industry, originally limited to the oxyacetylene process, had its beginning around 1903. Its development followed in the wake of commercial production of oxygen compressed in cylinders, first made available around 1907.

Although studies of the welded joint disclosed its many advantages, the innovation met with considerable resistance, as any new process usually does. This was due to the lack of skilled operators and supervisors, and a failure to appraise its potentialities. With the approach of World War I, the demand for metal fabrications, best produced by oxyacetylene welding and cutting, reached gigantic proportions. The overnight expansion of the industry resulted in added experience, a substantial increase in skilled personnel and a wider acceptance of the process.

The electric-arc welding process (known for a good many years) benefited equally from the war needs by meeting its opportunity for wider application with not inconsiderable success. The same windfall came to the resistance welding process which had been known even longer than the electric-arc process. Resistance welding met its challenge and came through the war with an equally good record of performance, added experience and a hopeful outlook. And so did the thermit welding process (the oldest of them all, and least known to industry in general). The priceless advantages gained from the war experience were put to good use in expanded industrial applications in the years following.

## The First Milestone

The first and most significant milestone in the advancement of the industry was the founding of the AMERICAN WELDING SOCIETY in 1919 with a membership of 219. Prior to this, the industry was largely in the hands of skilled craftsmen with a few technicians, an occasional engineer and practically no research laboratories or even facilities for making adequate tests. It was quite natural then that some welding applications were less than satisfactory. This was not necessarily due to any deficiency in the process, but rather to the overzealous operator, his meager understanding of the technique and less than adequate concept of the thermal and metallurgical aspects involved. Subsequently, when the engineers and the metallurgists entered the industry, they set up the laboratories, acquired or designed and built the testing devices and eventually put welding on a scientific basis.

The next milestone was the promulgation of the Code

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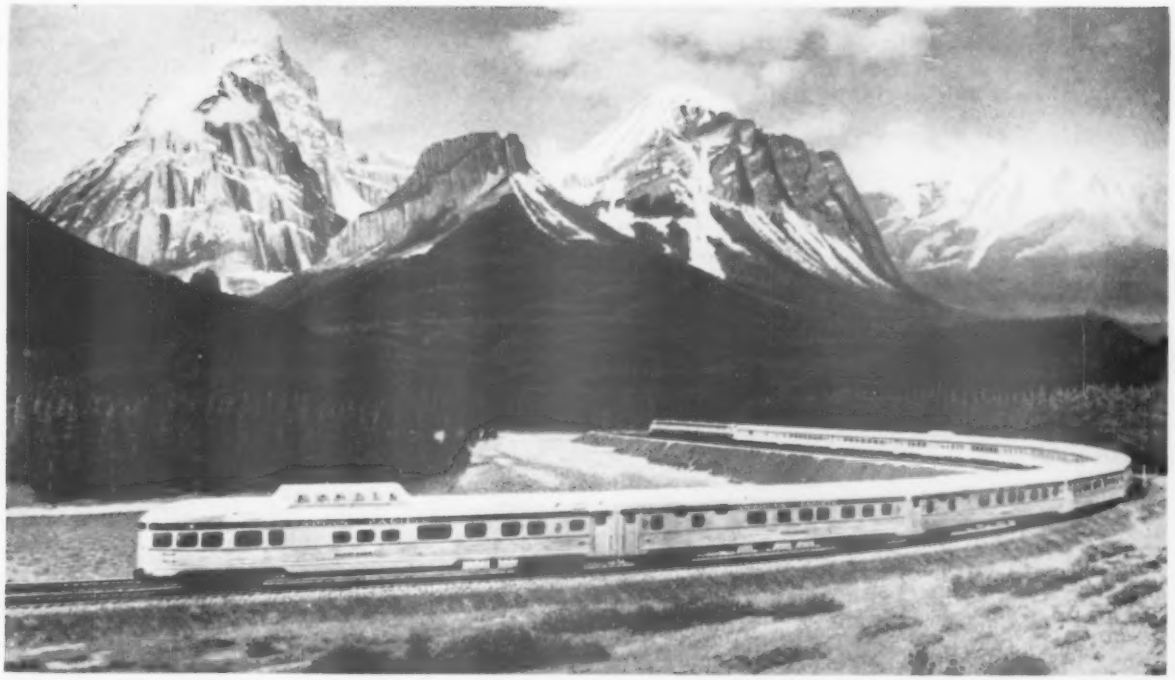

Fig. 2 "The Canadian," new Canadian Pacific all stainless steel transcontinental dome streamliner. Welding played a very important role in its construction

for Structural Welding. In order to overcome the natural resistance of some engineers and industrialists to the new process, and to set up scientific standards of dependability of a welded joint made under controlled conditions, the AMERICAN WELDING SOCIETY appointed a committee known as the Structural Steel Welding Committee. This consisted of representatives of the SOCIETY, the engineering profession and the steel industry. Under the capable supervision of this committee, numerous sample specimens of standard welding assemblies were made independently in various parts of the country under specified conditions. These samples were coded for identification and tested to destruction by independent laboratories. The tabulated results were remarkably uniform, and from them standard figures were developed for permissible loading per unit of weld in tension and in shear together with an agreed upon factor of safety.

The next step in the program of the SOCIETY was the organization of a series of standing Technical Committees to investigate and report on various phases of the welding process (some joint ventures with other societies). These reports subsequently became authoritative Standards or Codes universally accepted by the engineering profession and regulatory bodies, and incorporated into specifications for the contract purchase of welded assembles or erection of welded structures. There are over fifty such reports, and together they cover every technical phase of every type of welding in use. As soon as any new electrode or new welding process or technique is developed, or an existing one modified, a new study is made, and a Standard or Code set up to cover it. These are available for wide distribution to colleges, reference libraries, members of the SOCIETY, the engineering profession and any others who may be interested.

Another achievement in the SOCIETY's program was the modernization of building codes to permit structural welding. It was eventually attained in most parts of the country. Today, there are thousands of buildings of major proportion, including hospitals, apartments, warehouses and office buildings, in which all structural members have been welded, both in the shop and in the field. The welding of pipe for steam, water and refrigeration is practically universal in any fair sized building. And, of course, all transcontinental pipe lines for oil or natural gas are welded. Similarly, many bridges, cranes, towers and other massive structures are welded in part or throughout.

World War II brought with it unprecedented demands for welded assemblies of every description, in previously unheard of volume (see Figs. 1, 2, and 3). The industry met the demands in every way taking men from unrelated occupations and even adding housewives and salesgirls and making them all into acceptable welders. These novice welders helped build guns, tanks, ships and bombers, and met production schedules. There were problems, but they were solved promptly when brought into the daylight. Again the experience gained was put to good use in industry at the end of hostilities.

Welded ship construction started in World War I,

and reached its peak in World War II. Since then, practically all modern ships and tankers are welded—almost 100% up to and including the largest aircraft carrier recently put into service.

## Outstanding Applications

Perhaps the most outstanding application of welding is in the aircraft industry, where it is readily admitted that without welding the production of supersonic aircraft would be virtually impossible.

The same *sine-qua-non* statement can be made even more forcefully in the field of nuclear energy. Intricate assemblies of fuel elements used in nuclear power installations could not meet the extremely rigid specifications and tests required before use except by modern welding practice.

The welding of pressure vessels, boilers and complete petroleum refineries, with their intricate piping system, is a development to which the industry may point with just pride. At this writing there are in operation all-welded power plants, fully automatic in operation, using either coal dust, fuel oil or natural gas; whichever the instruments show are available at the moment. The operator sits at his "control board" and watches what is going on, but actually the electronic robots do the work. There are such plants now operating at pressures up to 5000 psi and temperatures up to 1200° F.

The young engineer entering the welding profession will find many facilities at his disposal to help him in his pursuits, principally: The AMERICAN WELDING SOCIETY with a membership of 11,000, organized into about 80 Chapters or Sections located in leading industrial centers throughout the United States; and, The WELDING RESEARCH COUNCIL founded by the Engineering Foundation about twenty years ago. The WRC has an annual budget of $500,000 (about one-third from government sources and two-thirds from industry) and allocates research projects to universities and other laboratories for the solution of complex welding problems. The information derived is made available to scientific and engineering groups and those interested in welding developments. The work of the Welding Research Council embodies the experience of leading experts in each field and is universally accepted as an authoritative reference in the solution of welding problems.

## Wide Choice of Professional Practice

A young engineer will find open to him a wide choice of professional practice in the welding industry which may include research, design, development, production, sales or a combination of any of these. He may find such opportunities with any one of a score of large manufacturers of welding equipment who maintain modern, well-staffed laboratories under a program of continuous research and development. This is imperative in order to safeguard their share of the market in welding equipment, materials, etc., which now totals over one billion dollars annually and is growing rapidly.

Even wider opportunities may be found with any one of a thousand companies in major industries in which welding has been a vital factor in their expansion.

Fig. 3 Hydraulic lift trailers, such as this one built by Clement-Braswell, Inc. are built to take rough treatment. They rely on strong, solid welds to maintain their peak payload performance

Among these, the following are typical: air conditioning, aircraft, appliances, automotive, construction equipment, nuclear energy, power, refineries, steel fabricators, transportation, etc.

An engineer in the welding industry will attain a broader experience than one limited to just his own branch. His practice is likely to bring him in frequent contact with other branches of the profession and constantly challenge him to meet their needs. These may involve structures for the civil engineer, power plants for the mechanical engineer, a refinery for the chemical engineer, a penstock for the electrical engineer, or a nuclear energy assembly or installation for the nuclear physicist.

Industry's needs for welding equipment and materials are well served by several large companies, each operating a chain of plants located in important industrial centers, a substantial number of independent plants operating in one or more localities, a large number of warehouses between centers and a still larger number of distributors locally owned.

Every metal-working union has craftsmen who are skilled welders. Some conduct training courses for their apprentices, and most trade schools now teach welding in an effort to meet the demands. Many employers have their own training group on company time for developing new welders and upgrading those with some experience. Engineering schools are also expanding their courses to include subjects of special interest to the industry and permit the candidates for a degree to major in this field.

Occasional buyers of welded assemblies or welded construction will find the country well spotted with local fabricators, welding contractors or job welding shops, ready to take on a job from a rough sketch to a blueprint with complete specifications and codes. To safeguard the buyer, there are local ordinances, boiler insurance companies' inspection services, the American Bureau of Shipping, certified welders' qualification tests, engineers and architects with welding experience to design and supervise qualified fabricators and shops who bid on the project.

All metals can be welded in almost unlimited thickness by one or more of the four basic methods now in use—namely gas, arc, resistance and thermit. Each of these methods has its preferred application, using its own type of equipment (readily available), follows a standardized technique and generally uses a filler rod or electrode manufactured under standard specifications and so labeled. Some methods can be applied manually, some have been mechanized, some are semi-automatic and some are fully automatic.

A not unimportant part of the welding industry is the cutting of metals with the oxyacetylene torch or electric arc. The former process can be applied by hand or can be mechanized with an electric eye following a blueprint and controlling several dozen torches. These torches are automatically propelled over a stack of steel plates, accurately cutting and dropping out at one time over one hundred identical pieces which can frequently be used without additional machining. The oxyacetylene torch can also be used for rough-cutting heavy threads or large gears, often without requiring additional machining. It is also used for flame hardening carbon steels or for paint and scale removing.

Nonferrous metals, cast iron and stainless steel are being cut very successfully with the oxyacetylene torch by the introduction of a chemical flux or iron powder. They may also be cut with the arc-oxygen torch using a flux-coated tubular electrode. This method is also being used to cut all metals under water, using the same electrode properly waterproofed.

A special technique also permits arc welding under water, using a suitable electrode properly waterproofed. Underwater cutting and welding rendered valuable service during the war and are being used in salvage and marine construction.

## The Outlook

While one or two universities are now offering a specific degree in welding engineering, the engineering work in the industry is in the hands of the usual branches, largely mechanical, civil or metallurgical, with a sprinkling of electrical, chemical, mining and industrial. All of them have had minimum courses in metallurgy, structural design, strength of materials, etc., in their undergraduate work, or taken them at a later date in extension work readily available in any engineering school.

Although the industry is almost fifty years old, it is still a very young industry with tremendous possibilities for expansion and development. While every industry is constantly revamping its design in order to incorporate more welding because of its numerous advantages, the welding industry is redesigning its products or developing new processes to meet existing production demands. At the same time it is pioneering along new lines and constantly introducing new and improved features; so that a good percentage of the business done in 1957 may be on items that existed only experimentally ten years ago.

## A Challenge to Creative Ability

The young engineer will find the industry a distinct challenge to his creative ability, imagination and resourcefulness. Mass production, mechanization and automation are the milestones ahead of us. Comfortable living, greater leisure and extended travel are some of our goals. Welding is the universal tool that can build and maintain the milestones and make the goals attainable.

A billion dollar industry is not a big industry when measured by modern yardsticks, but the welding industry yields to none in its accomplishments, its war service and its contribution to the advancement of civilization, from the singing tea kettle on the stove to the jet liner overhead—both proven welded products. It promises even greater service toward peaceful enjoyment of a longer and richer life in harmony with the rest of the world, as we know it now, or as it may be revealed to us at a later date.

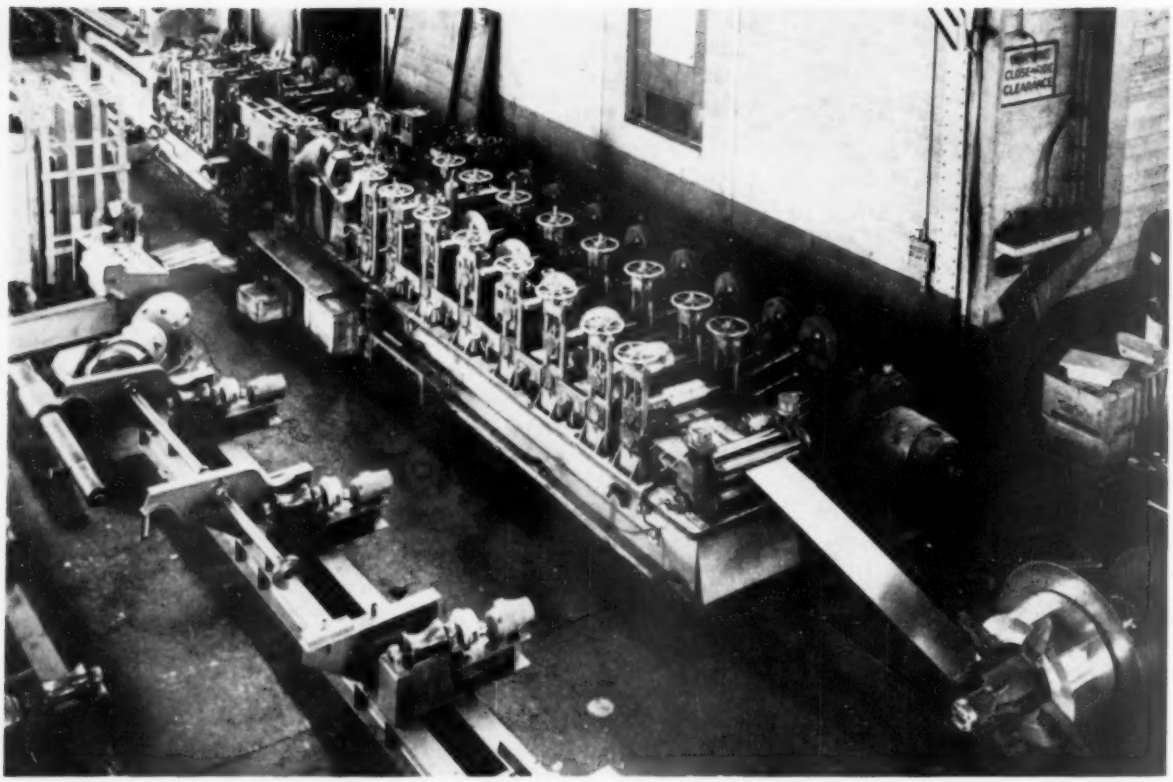

Fig. 1 Over-all view of aluminum tube mill

# AUTOMATIC INERT-GAS-SHIELDED TUNGSTEN-ARC WELDING OF ALUMINUM ALLOYS

*Investigation leads to the successful use of alternating current with the existing automatic inert-gas-shielded tungsten-arc equipment in welding aluminum alloys*

BY H. D. MANN AND R. E. PURKHISER

SYNOPSIS. It has been well established that welding assemblies that must exhibit very closely controlled mechanical properties are readily obtainable through use of automatic inert-gas-shielded tungsten-arc welding. Until recently, however, equipment for application of this process has been limited to use with direct current. Since use of this equipment with alternating current would also be desirable, particularly in welding of aluminum alloys, an investigation was undertaken to determine if this could be accomplished.

The use of alternating current with existing inert-gas-shielded tungsten-arc welding equipment, it was found, requires insertion of a means for converting an alternating current signal into an essentially direct current signal for the present control system. This is accomplished with an auxiliary piece of equipment consisting of the items necessary to utilize the stable portion of an alternating current signal for rectification purposes.* Examination of the alternating-current arc showed erratic firing on the reverse-polarity half cycle of the alternating-current wave but the straight-polarity half was reasonably stable. The auxiliary piece of equipment which permits the use of alternating current with existing process apparatus was therefore designed to utilize only the stable portion of the alternating-current wave.

In developing the auxiliary equipment, process variables were all important since they govern the stability of an arc. Variables affecting stability in this case were found to be current density, gas flow, arc length, tungsten type and the effect on the arc column of adding filler metal. Once proper values for these variables were determined, a stable arc was obtained and the use of alternating current with inert-gas-shielded tungsten-arc

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* Patented.

welding equipment was made possible. Another factor that had to be taken into consideration during the investigations was the output of power supplies. Investigation indicated that these must exhibit stable characteristics and have a sufficiently high open-circuit voltage.

As a result of all studies, a practical system for the use of alternating current with present inert-gas-shielded tungsten-arc welding equipment in the welding of aluminum alloys was developed. In its broadest application, it should prove exceedingly valuable to the aircraft and allied industries where very closely controlled welded assemblies are mandatory.

## Introduction

It is the purpose of this paper to report on the investigation that led to the successful use of alternating current with existing automatic inert-gas-shielded tungsten-arc welding equipment in the welding of aluminum alloys.

Prior to this time, attempts have been made to use alternating current with existing equipment to weld aluminum automatically, but results have fallen short of satisfactory. Under certain restricted conditions, aluminum *has* been welded in the past using direct current, straight polarity, but, in general, the use of alternating current is required, and it was to make this possible with existing equipment that present investigations were undertaken.

## Aluminum Welding with Direct Current, Straight Polarity

As has already been stated, welding of aluminum using direct current, straight polarity has, in the past, been accomplished. Conditions are so restricted, however, that successful accomplishment cannot ordinarily be obtained under usual shop conditions.

The welding of aluminum with direct current requires helium shielding gas and thoriated-tungsten electrodes. It is also necessary to remove surface oxides, and the parts to be welded must have a perfect fitup. A successful example of the welding of aluminum using direct current, straight polarity under the conditions outlined is illustrated in Figs. 1 and 2 which show an aluminum tube mill in operation. In this application, an aluminum strip is fed into the forming mills, surface oxide is removed by stainless-steel wire brushes and the fitup is presented to the welding arc in a uniform manner.

The particular operation shown in these figures was accomplished at welding speeds in the order of 20 to 50 fpm. The high welding speeds were obtained by taking advantage of the deep-penetration characteristics of the helium shielding and the preheating of the pipe just prior to welding.

## Aluminum Welding with Alternating Current

Since the restricted conditions necessary for welding aluminum with direct current cannot always be as successfully attained as they were in the operation shown in Figs. 1 and 2, the fabricator has had to resort most often to use of alternating-current welding in handling aluminum alloys. In general, results to date have been unsatisfactory due primarily to the fact that proper equipment has not been available to provide a satisfactory control. Lack of understanding of important process variables has also been a stumbling block.

In seeking a solution to the problem of successful welding of aluminum with alternating current, practical considerations led to the investigation of ways in which to adapt present inert-gas-shielded tungsten-arc equipment for this purpose. In using existing process equipment, it was found that an apparatus had to be designed which would rectify alternating-current signals and convert them to direct current before they would be effective with the equipment's existing servo system. This servo system senses changes in arc voltage as the result of changes in arc length. The direct-current amplifier used to control a motor in systems of this kind is rather well established. However, when alternating current is used as the welding power, arc instability is experienced which results in fluctuation of arc voltage and unstable operation of the direct-current amplifier system. This had to be overcome as it is evident that the arc must be stable before any apparatus that is voltage sensitive can function correctly.

In looking at an oscillogram of an alternating-current voltage, it was found that the voltage wave was not completely uniform. However, one half of the voltage wave, the straight-polarity half, was reasonably uniform and proportional to arc length. By using this half cycle and rectifying it, a new piece of equipment could be developed to provide a suitable signal for the present direct-current amplifier.

## Process Variables

During the investigation, it was found that process variables as well as the output of welding machines

Fig. 2 View of automatic equipment and sample of welded tubing

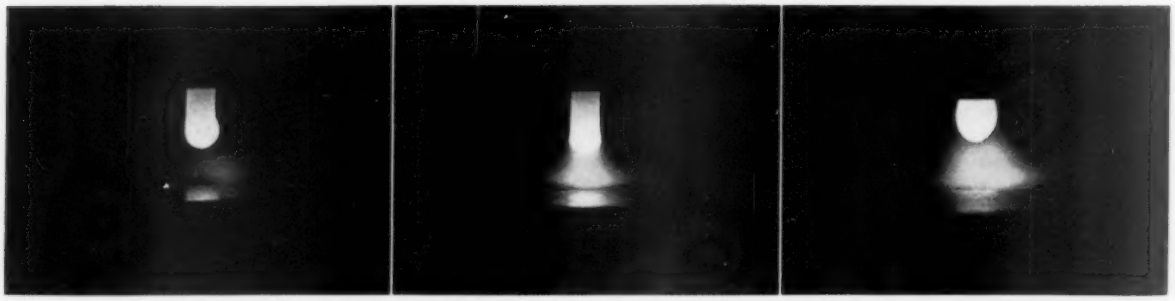


Fig. 3 Alternating current, $^3/_{32}$-in. pure tungsten electrode

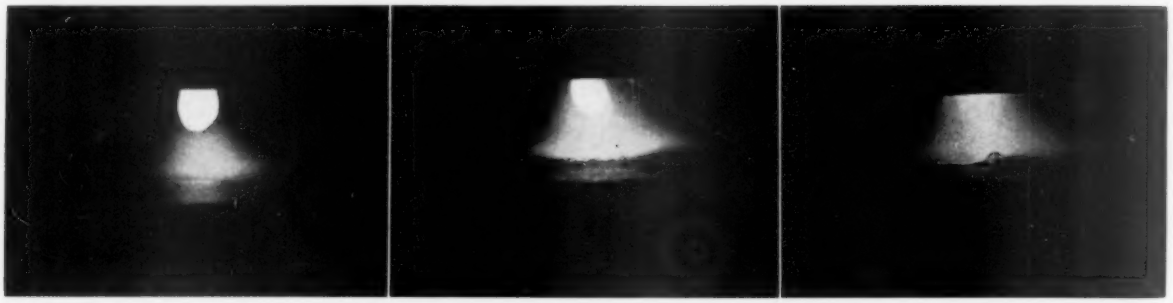


Fig. 4 Excessive current (ac)

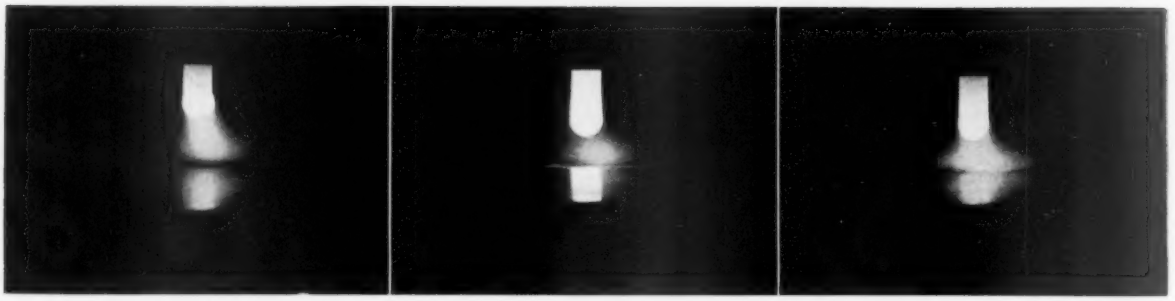


Fig. 5 Effect of varying argon flow on arc column

affect arc stability. Process variables which were studied in the course of the investigation were: current density, gas flow, arc length, tungsten type and filler-wire additions.

## Current Density

With respect to current density, the effects on an arc of both too little and too much current were studied. Too much current, it was found, resulted in an erratic arc caused by the tungsten overheating and causing spitting to occur. Too little current produced arc instability caused by arc wandering.

Figure 3 shows arcs produced by optimum, too much and too little current. In all three cases, $^3/_{32}$-in. diam pure tungsten was used. The photograph in the center shows the arc produced by an optimum current. At the right, too much current was used, causing spitting and, at the left, too little current was applied, producing arc wandering. The effect of this latter can be seen in the photograph by noting the relatively weak arc plasma.

Tungsten spitting, caused by too much current, gives a higher than normal arc voltage (Fig. 4) and since the automatic sensing system of the welding equipment reflects the arc voltage, the machine barrel drives the electrode into the work. Frequently, this effect is cumulative and continues until the electrode is actually caused to short the work.

As a result of studies, it has been found that there is an optimum current range for a specific diameter electrode. Equipment design can contribute to increasing this range by making provisions for keeping the tungsten cool.

## Gas Flow

Applications encountered to date indicate that argon is the only practical shielding gas for welding aluminum alloys with alternating current automatic inert-gas-shielded tungsten-arc equipment. The amount of gas flow used can be very important in achieving arc stability.

Effects of changing gas flows are shown in Fig. 5.

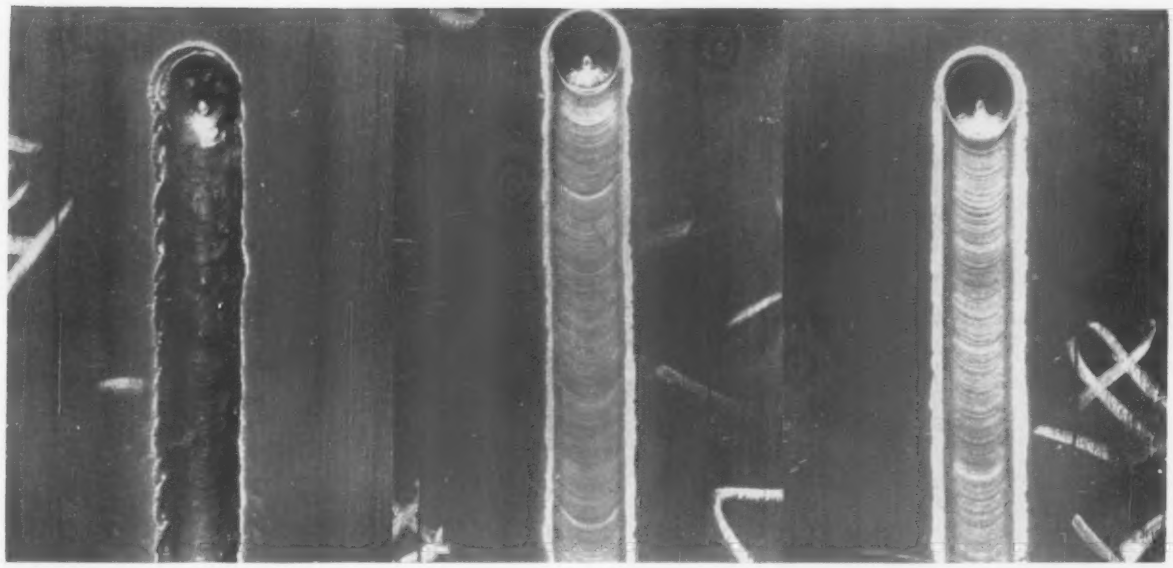


Fig. 6 Effect of varying argon flow on bead appearance

In the test illustrated, 5 cfh (left) was found to be an insufficient amount, while flows of 10 cfh and 12 cfh (the two photographs at right) proved adequate and produced stable arcs. (These values may vary with different designs of equipment.)

In the case of too low a gas flow, erratic firing of the arc is experienced. This erratic firing results in an irregular arc voltage and, consequently, an irregular signal to the servo system causing erratic action. Very often, the result is sluggish response in holder positioning.

Too much gas flow is similar to too low a current density in that the electrode is too cool to provide a stable arc. Figure 6 shows the arc-sputtered areas adjacent to welds that are produced by different gas flows. An excess flow of gas and its resultant effect is shown at the right in Fig. 7 where 24 cfh have produced an erratic bead and an excessively broad arc-sputtered area. The ideal condition is shown in the adjoining picture.

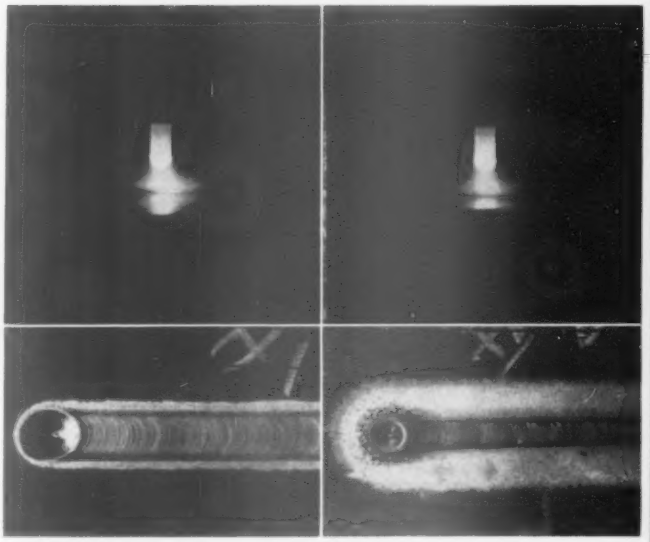


Fig. 7 Normal and excessive argon flow

## Arc Length

Application of alternating current in inert-gas-shielded tungsten-arc welding indicates that it is advantageous to operate with longer arc lengths than those usually employed when using direct current with argon shielding. An explanation for this might be that too-short an arc length results in an increase of reflected heat which causes the tungsten to overheat, giving the same effect as a high current. Too long an arc will give too wide a bead and a possible increase in the heat-affected zone.

## Tungsten Types

A comparison between pure tungsten and thoriated tungsten with alternating current was made to determine their effects on arc stability. In Fig. 8, a comparison between pure and thoriated tungsten under similar conditions is shown. The pure tungsten (left) provided a uniform surface as compared to a somewhat irregular surface at the end of the thoriated tungsten (right). Surface irregularities give a nonuniform transfer of electrons and since any surface irregularity tends to give an unstable arc, pure tungsten is usually recommended for alternating-current welding.

## Filler-Wire Additions

Application of automatic equipment requires that optimum process conditions prevail. Considerations of proper amount of current, electrode size, gas flow and power source are important. Also important, however, is consideration of filler-wire addition.

When filler wire is used for weld reinforcement with

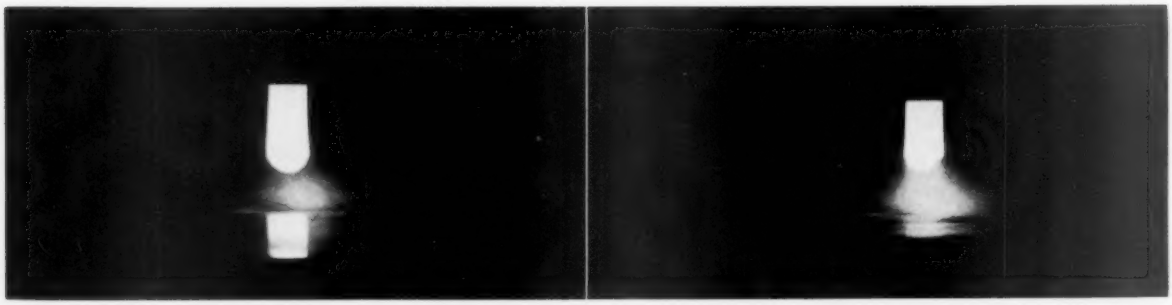


Fig. 8 Tungsten type using 140 amps ac

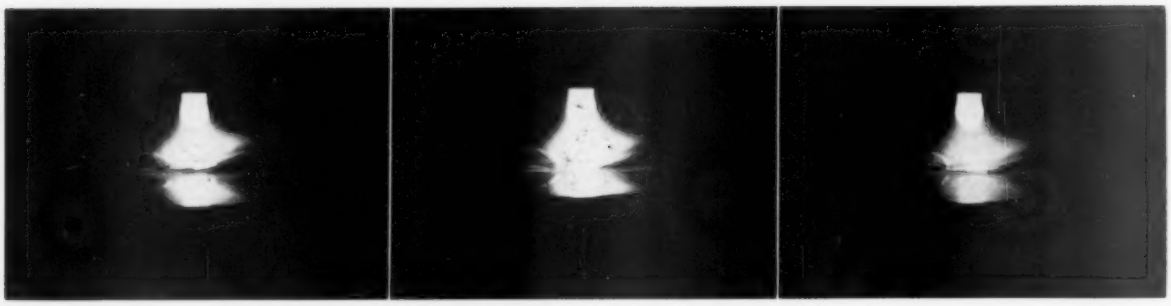


Fig. 9 Proper filler-wire addition; $^{3}/_{32}$-in. electrode, 185 amps ac and $^{1}/_{16}$-in. 4043 wire

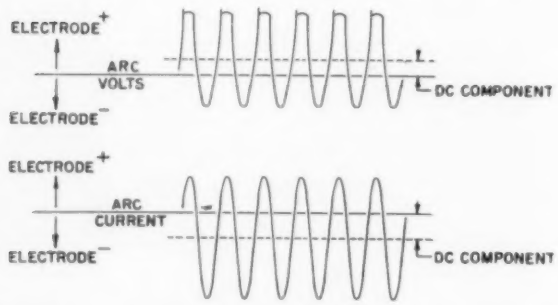



Fig. 10 Voltage and current rectification in an a-c aluminum arc

automatic inert-gas-shielded tungsten-arc equipment, an additional source of arc disturbance is created. Extremely important is the manner in which the filler wire is directed. If the filler wire is not properly directed, it will interfere with the arc column and result in erratic operation.

Ideally, the filler wire should wet into the weld puddle readily and completely. If the wire does not fuse into the puddle properly, droplets of wire can roll under the electrode and interfere with the arc column.

A properly directed filler-wire addition is shown in Fig. 9. The three sequences show a droplet of wire as it wets into the puddle.

## Alternating-Current Signal Variables

Oscillograms of welding currents were made with two factors in mind: characteristics of alternating-current arcs, and characteristics of welding machines.

## Characteristics of Alternating-Current Arcs

Most alternating-current power supplies provide an essentially true sine wave when no load is applied. When a welding-arc load is presented to the power supply, however, the wave form changes radically.

In Fig. 10, an oscillogram of a wave shape produced by presenting a welding load is shown. It should be noted that the voltage wave, although nonsinusoidal, is rather uniform during the lower or straight-polarity half of the cycle, whereas on the reverse-polarity half cycle, the signal is distorted. The voltage distortion is caused by the fact that the arc resistance is nonlinear. The extreme distortion on the reverse-polarity half cycle as compared to the straight-polarity half is due to the fact that the electrode is the anode on the reverse half and requires greater voltage for ignition.

The reverse- and straight-polarity half cycles are not balanced and the result of the unbalance is the direct-current component. This is shown graphically in Fig. 10 by the dotted lines displaced from the reference in both the current and voltage wave form.

## Characteristics of Welding Machines

In the design of an inert-arc welder, a means must be provided to insure arc ignition on both half cycles. The reverse-polarity half is more difficult to ignite than the straight-polarity half. Two designs of welding machines have been made available to provide proper ignition on the reverse half cycle. The most widely used system is the one that utilizes a continuous high frequency. An oscillogram of the output of this machine is shown at the right in Fig. 11. The high frequency is used to start and maintain the arc. By

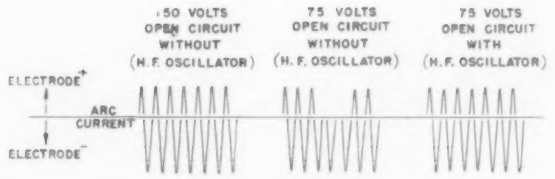



Fig. 11 Effect of open-circuit voltage on arc stability

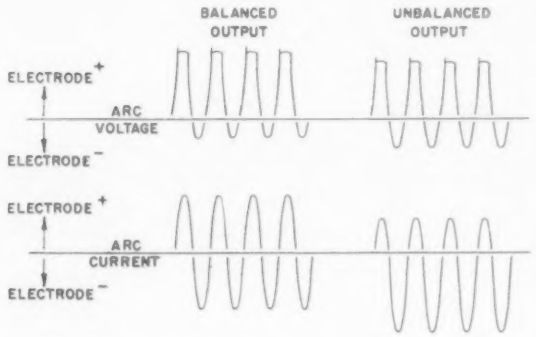



Fig. 12 Current and voltage in balanced and unbalanced outputs

"starting" is meant the initial arc ignition, while "maintaining" refers to arc reignition each half cycle. Considerable testing was done on the continuous high-frequency design type and the open-circuit voltage was found to be an important factor. Test of machines with open-circuit voltages in the order of 65 to 70 v gave erratic arcs, whereas open-circuit voltages of 80 gave good arc stability.

Another machine design utilizes high voltage to reignite the arc on the reverse-polarity half cycle. An oscillogram of this type machine which employs open-circuit voltages up to 150 v is shown on the left in Fig. 10. This machine employs a high-frequency oscillator although the oscillator is used only for starting the arc. The middle oscillogram shows the condition that occurs when sufficient ignition voltage is not obtained. This results in an erratic arc action since the arc is out at times.

Figure 12 shows an oscillogram of voltage and current for both types of machines. The balanced output is that produced by a high-voltage machine. By "balance" is meant that current wave is balanced. Unbalance seen in the oscillogram of the voltage wave is necessary to provide a uniform current wave.

The direct-current component referred to previously under the heading "Characteristics of Alternating-Current Arcs" is a consideration in the design of an inert-gas-shielded arc welder. Since any direct current tends to saturate a transformer core, an inert-arc welder must have a larger core than conventional alternating-current welding machines of the same rating.

## Equipment Installation

In the application of automatic equipment, the use

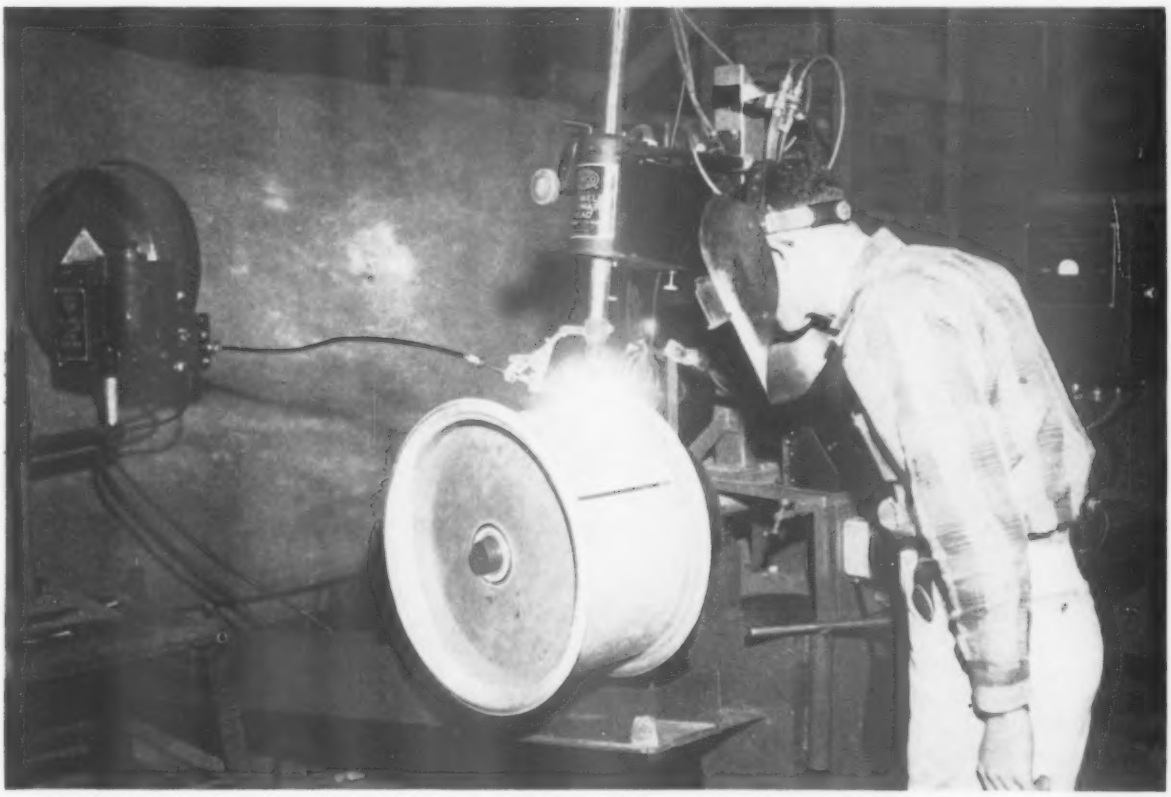


Fig. 13 Circumferential lap fillet weld being made on 61S aluminum

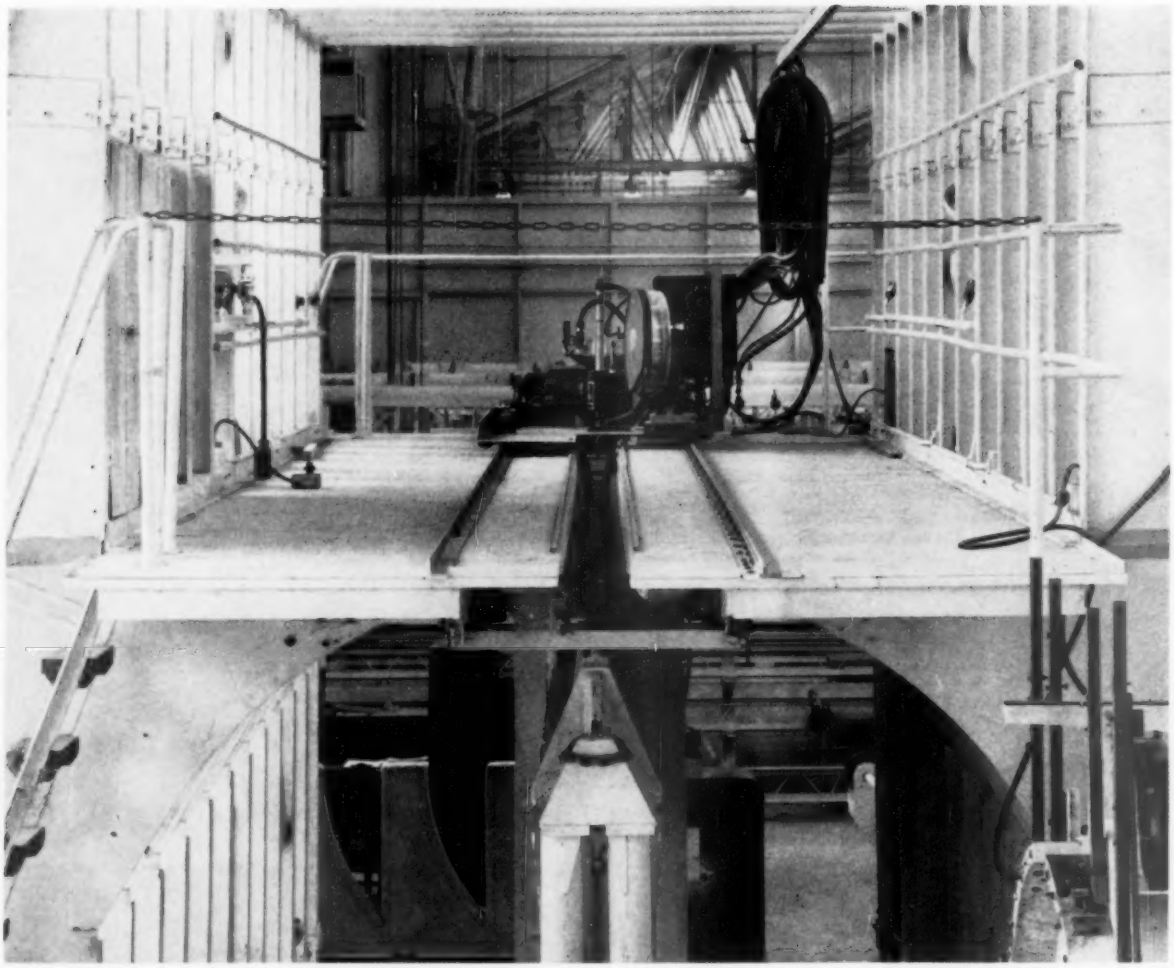


Fig. 14 Automatic equipment mounted on a typical welding fixture

of high frequency presents problems that are not evident when direct current is used. In order for high frequency to be available to start and stabilize the arc, it must be available between the tungsten and the workpiece. To assure this, the following rules of good practice should be observed:

1. The lengths of the weld current leads should be kept as short as possible since short leads insure that high frequency will be available for starting and stabilizing the arc.

2. The electrode lead should be clear of control cables to minimize the possibility of high-frequency pickup by the control circuits.

3. The electrode lead should be spaced away from large metal objects to prevent dissipating the high frequency.

4. If long leads are necessary, the high-frequency unit should be installed at the welding head.

5. Shielding of the control cables is desirable.

If these installation techniques are not observed, two things will usually occur. First, the high frequency will be picked up by the control circuits; this type of pickup tends to block the operation of the sensing system and causes sluggishness or even complete lack of arc-length control. Second, the high frequency will be dissipated, meaning that it will not be available at the electrode and workpiece for optimum ignition. Erratic arc ignition always results in a rise in arc voltage. If this rise in voltage is sustained for more than a short interval, it will cause the arc length sensing system to drive the electrode into the weld puddle.

## Applications

Applications of automatic inert-gas-shielded tungsten-arc welding on aluminum using alternating current are illustrated in Figs. 13, 14 and 15.

Figure 13 is a view of the automatic equipment in operation using a filler wire feeder. The material is 618 aluminum 0.091 in. thick. A lap-fillet weld is being made. Welding speeds are in the order of 15 ipm.

Figure 14 shows the equipment mounted on a horn-type fixture that can be used to weld 40-ft long sections up to 20 ft in diameter. The unit has been used

to weld 24S aluminum approximately $^3/_{32}$-in. thick at speeds in the order of 12 ipm.

In Figure 15, a butt weld in 14S material approximately 0.100-in. thick is being made. The welding speed is in the order of 10 ipm.

## Conclusions

In order satisfactorily to apply automatic equipment when alternating current is used with the inert-gas-shielded tungsten-arc process to join aluminum alloys:

1. A stable arc must be presented as an arc signal for the sensing equipment, with particular emphasis being placed on current density, gas flow, type of electrode, arc length and filler metal.

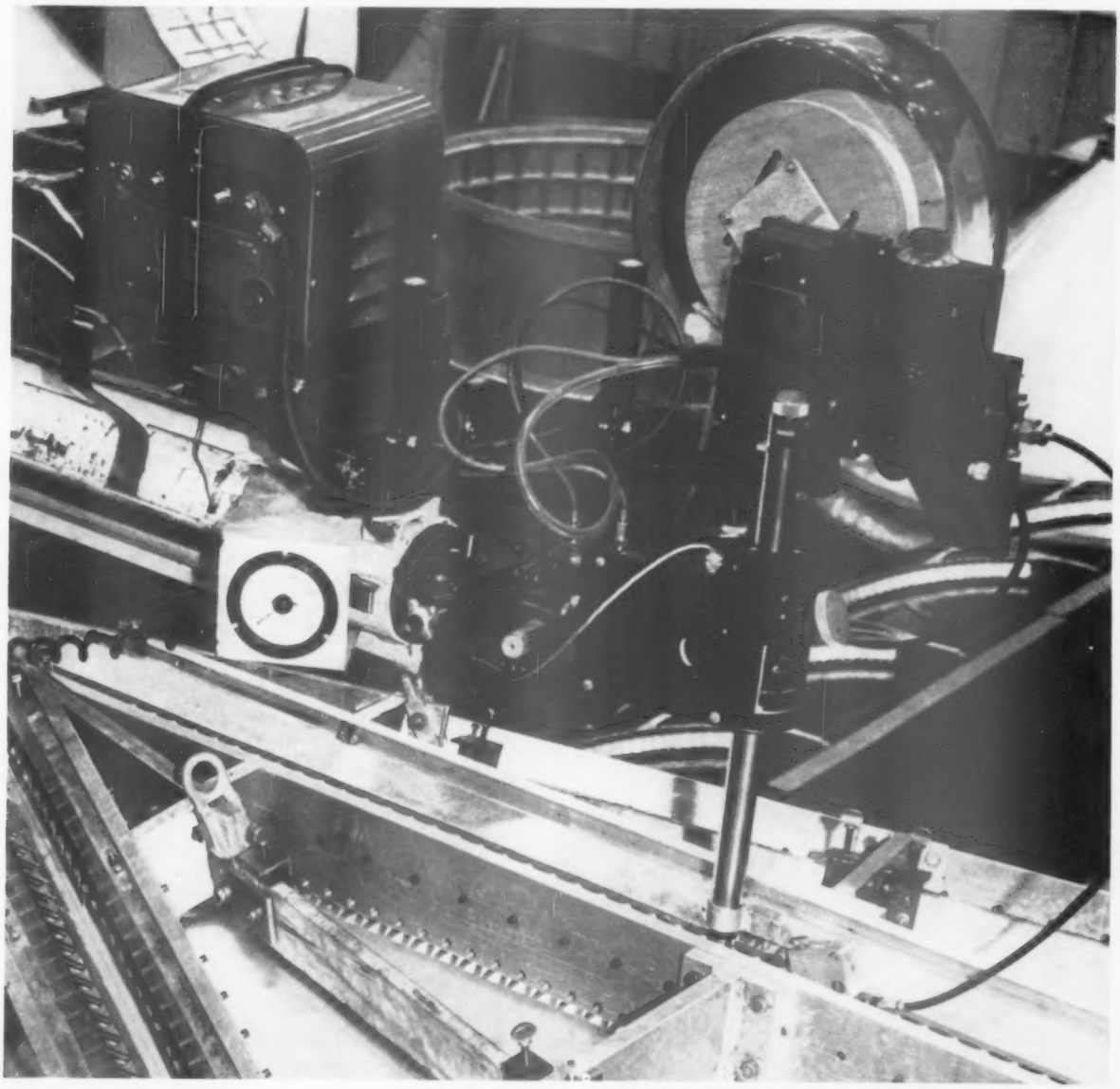
2. The power supply selected must be one that is specifically designed for inert-gas-shielded tungsten-arc welding and, if a power supply using continuous high frequency to maintain the arc is used, it must have an open-circuit voltage in the order of 80 v.

3. Good installation practices must be used to insure that high-frequency pickup does not block out the servo system and that high frequency is available to start and maintain the arc.

*Acknowledgment*

The authors wish to express their gratitude to the personnel of the Air Reduction Central Research Laboratories technical staff who by discussion contributed greatly to the information contained in this presentation. Particular thanks go to the photographic laboratory personnel who made the photographs and graphs used.

Fig. 15 Automatic equipment making a weld on 14S aluminum

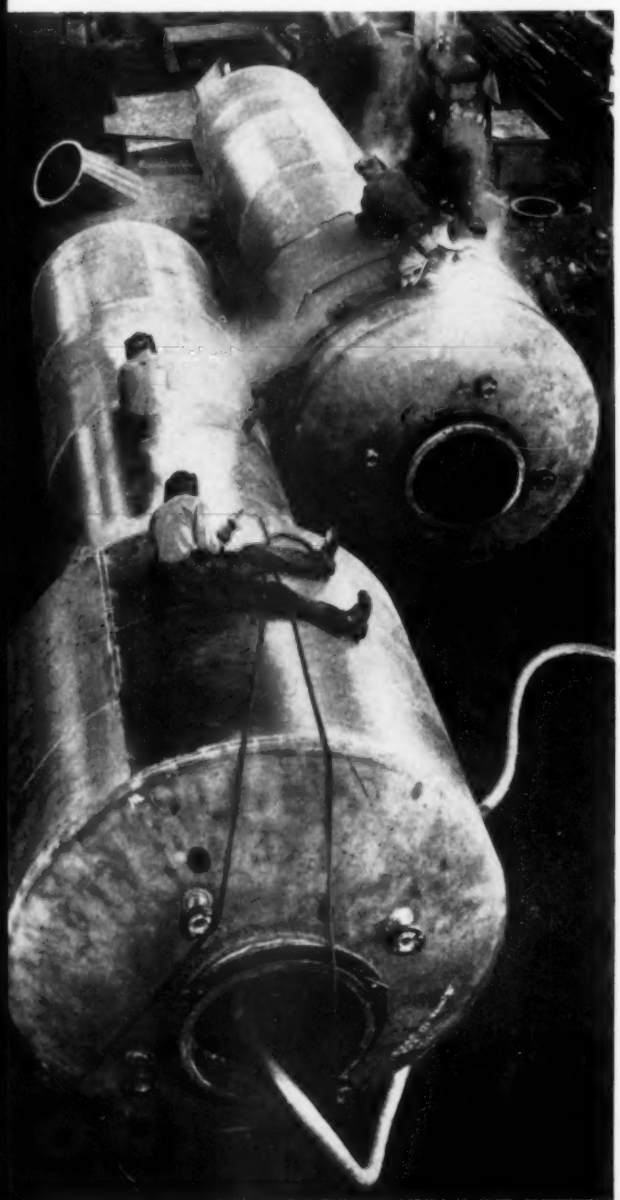


# ELECTRODE CONTROL IN AN ALLOY PRESSURE-VESSEL PLANT

*To meet the stringent demands being made of weld metal deposits, control of the electrodes and filler wires is important*

BY W. W. WEBER

Fig. 1 Typical welding operations in an alloy pressure-vessel plant



## Introduction

To initiate an effective electrode control system, it is necessary to meet with all welding supervisors, lead men and storekeepers to outline in detail, the procedures which must be followed. These men are the key to the ultimate success or failure of such a system. The author believes that these key personnel, properly briefed in the benefits which can be derived by an effective control system, will achieve the ultimate goal with a minimum expenditure of effort.

An incubation period of two to three months is necessary to aquaint welding personnel with the various aspects of the program and this, in effect, is an educational program. It is important that all welding personnel be made aware of the disastrous and costly results which may be encountered if the improper electrode or filler wire is used.

## Selection of Welding Process

Before we can decide upon the proper filler wire or electrodes to be used on any given project, it is advisable to determine the most practical and economical welding process which can be applied with the utmost advantage. In a medium-size manufacturing plant, however, it is not always feasible to use the optimum welding process due to the limited welding equipment and the work-load conditions which prevail at that time. It is important, therefore, that the final decision as to selection of a welding process be made by qualified welding personnel closely related to production welding.

Selection of the welding process for each project should be considered while in the estimating and design engineering phase, so that proper quotations can be made and the selected joint design and geometry can be incorporated on the drawings. Joint design selection is also vital at this stage so that orders for component parts which are fabricated by other vendors may be placed. In this manner, promised delivery schedules can be maintained.

**W. W. Weber** is Welding Engineer, Colonial Iron Works Co., Cleveland, Ohio.

Presented at the 1956 AWS National Fall Meeting in Cleveland, Ohio, October 8–12.

We now advance to the process engineering department where final details of the project are reviewed. At this point the welding procedure is written and turned over to the process engineer. The welding procedure tells the process engineer the size, class and type of electrodes or filler wires to be used on the project. He then determines the amount needed and transmits this information to the "General Stores Manager" on a material requisition form.

This concludes the engineering phase of electrode control and we are ready to move on to the next step.

## Inventory Control and Storage

As mentioned previously, the class, type and required amount of filler wire or electrodes are listed on a material requisition form and transmitted to "General Stores." Personnel in this department check the requirements listed on the requisitions against a master file of running inventory cards each week. Herein lies the "heart" of a good electrode control.

Electrode inventory is based on the tonnage used in previous years, although new materials and their filler wires must be taken into consideration as they enter the field of fabrication. Class of electrode, such as E-308, E-309, E-310, E-316, etc.; type of coating, whether lime, titania, or lime titania, bare coiled wire for submerged-arc welding, consumable-electrode inert-gas welding; and the minimum amount of each size and class that should be carried in stock are predetermined by qualified welding personnel. The author suggests that only those types of electrodes and filler wires consistently used be regularly stocked. Modified or special types of electrodes are not carried on inventory but are ordered as required. A practical minimum quantity of electrodes selected for inventory assures two things:

A. The danger of running out of a certain size, class or type of filler wire is minimized, thereby preventing such disastrous results as upsetting an entire production schedule and delay of tight delivery schedules.

B. Excessive amounts of electrodes are also avoided to insure a fresh supply, conserve storage space and keep electrode minimum at a practical figure, dollar wise.

As electrodes are received from the supplier, they are stored on racks according to AWS classification; thus, when three or four different classes of electrodes are called for on electrode requisitions from production, the storekeeper can immediately locate them. Sizes and types are also stored separately and packages are not opened until needed in production. An area which is dry is naturally selected for storage of electrodes.

## Care of Electrodes in Production Areas

In order to withdraw alloy electrodes or filler wire from "General Stores," it is necessary for the lead man

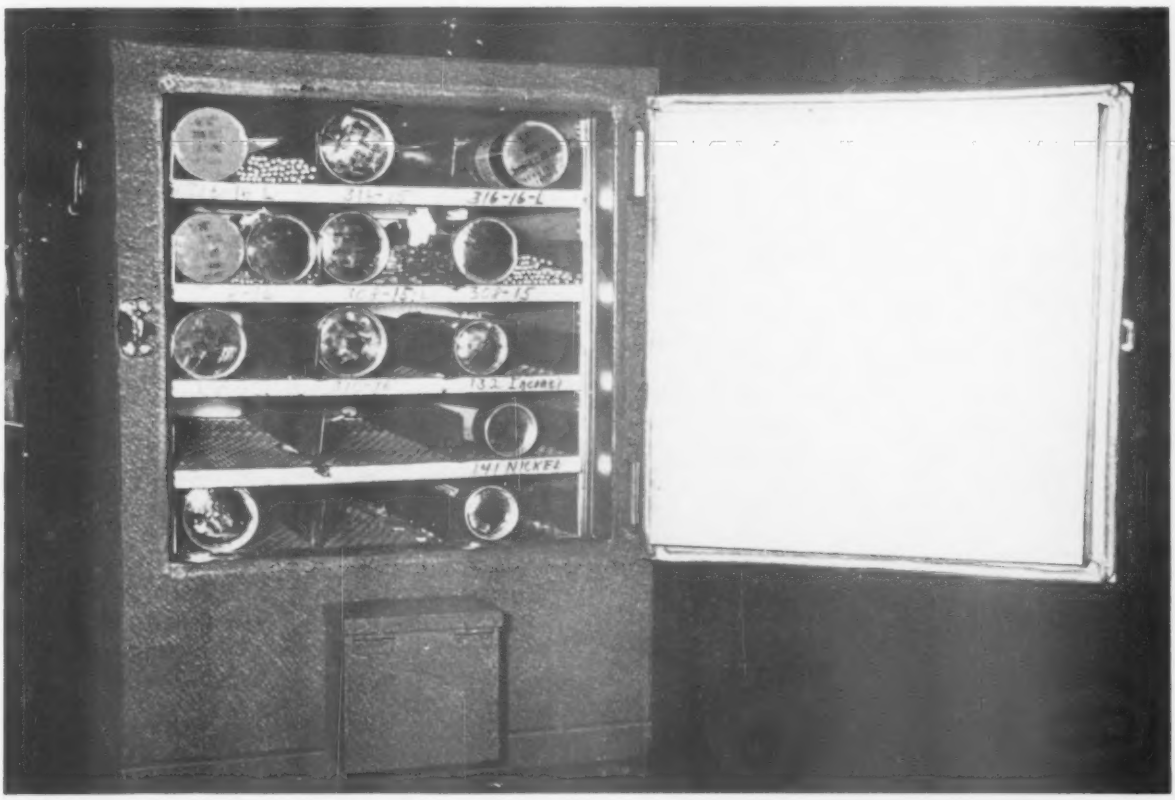



Fig. 2 Electrode storage oven with identified compartments

or welding foreman to fill out a requisition stating the class, type, diameter and the project number. After electrodes have been withdrawn by production personnel, the lead man in charge of the job is responsible for the use of electrodes as specified by the welding procedure. Most alloy electrodes are supplied in ten-pound containers and, depending upon the number of welders working on the project, a limited number of packages are opened for use.

At the end of each welder's work day, the welder is requested to take the electrodes which remain in the containers and place them in properly identified compartments in electrode drying ovens in strategically located areas (Fig. 2). This procedure will normally aid in the prevention of moisture pickup by the coating and, also, prevent damage to the coating which can result if electrodes are left lying on the workpiece or floor for an extended period of time.

The work areas are inspected at the end of each shift by the supervisor in charge to see that this phase of the program is properly executed. Upon completion of a project, all surplus electrodes are returned to "General Stores" where credits are properly entered. In this manner, we can check actual usage of electrodes and filler wire against the original estimate for accuracy in determining future estimates and, also, use the returned electrodes on other projects which call for this class of electrode.

## Electrode Identification

At this point, the author would like to discuss identification of electrodes. While it does not have a direct bearing on electrode control, the incidence of identification is of importance.

The problem of electrode identification in an alloy fabricating plant is becoming more difficult, as it may be necessary to stock up to thirty or more classes and types of electrodes. The NEMA color standards are being used with fair consistency by the majority of electrode producers but the identification on the containers in which they are packed is hopelessly confusing.

The AWS, ASTM, and other organizations have set up and published, standard numerical designations for various electrodes and filler wires. It is unfortunate, however, that these numerical standards are not properly used by all electrode producers. Let's take a closer look at this situation from an alloy fabricator's viewpoint.

Since we are using a majority of all classes and types of alloy electrodes, and because some manufacturers of electrodes do not produce all the various classes and types, it becomes rather apparent for these and other reasons to have at least two or more primary sources of supply. Each of these sources of supply identifies these packages and cartons in a different manner. To illustrate, let's look at three typical examples imprinted on the carton in bold type:

A. Staybrite 67
B. Hammond RTD—18-8
C. Acehigh X-6308

Since the purchasing department buys electrodes to AWS and ASTM numerical designations, these brand names mean nothing to the purchasing agent, storekeeper or welder but, rather, add to the confusion. Now, upon closer scrutiny of the carton with a magnifying glass, we find at last that all three cartons contain electrodes conforming to AWS or ASTM Spec. E-308-16. We now are ready to use the electrodes in production and we open the cartons to get at the individual containers in which the electrodes are sealed. These containers identify the electrodes within in several ways. Two of the most commonly used are (1) a label on which is imprinted typical chemistry of weld deposits, current to be used, and chrome nickel content, as shown in Fig. 3; or (2) this same information may or may not be imprinted on one or both ends of the electrode container, as shown in Fig. 4.

In case (1) where a paper label is attached to the container and no other identification is imprinted on the container, identification is rapidly lost in production when the label comes off.

In case (2) where the brand name, type of current, and chrome-nickel content is imprinted on the ends of the container, loss of identification of the electrodes in production is not as critical. Taking a closer look at case (2), we find one thing missing—the numerical designation denoting type of coating.

The author suggests that all electrode producers boldly imprint the electrode cartons as well as the ends of the electrode containers with the numerical designations issued by the AWS and the ASTM as the primary identification, and use their brand name as secondary identification in smaller print. This will avoid confusion in the "General Stores" department and loss of electrode identification in production will be at a minimum. We cannot expect each and every welder to be an expert on color identification, but with standard numerical designations as used by the AWS and ASTM, training of all personnel involved, with readily available literature, becomes easy.

## Responsibilities of Personnel Involved

An electrode control program can function only as efficiently as the personnel involved make it. The "electrode control" man or storekeeper should review his inventory each week to insure that minimum quantities of each class, size and type of filler wire is maintained in stock. Secondly, he should make sure that each class of electrode is properly separated to minimize the danger of issuing the wrong electrodes to production. He should always use the oldest stock of the class of electrode called for on the shop requisition and be sure that charges and credits of electrodes are entered against the right orders.

The requisitions from the "electrode control" man to the purchasing agent should be carefully scrutinized by the purchasing agent for classification and type discrepancies, and it should also be the purchasing agent's duty to purchase electrodes at the most favorable quantity, price wise.

Lead men and welding supervisors must follow the

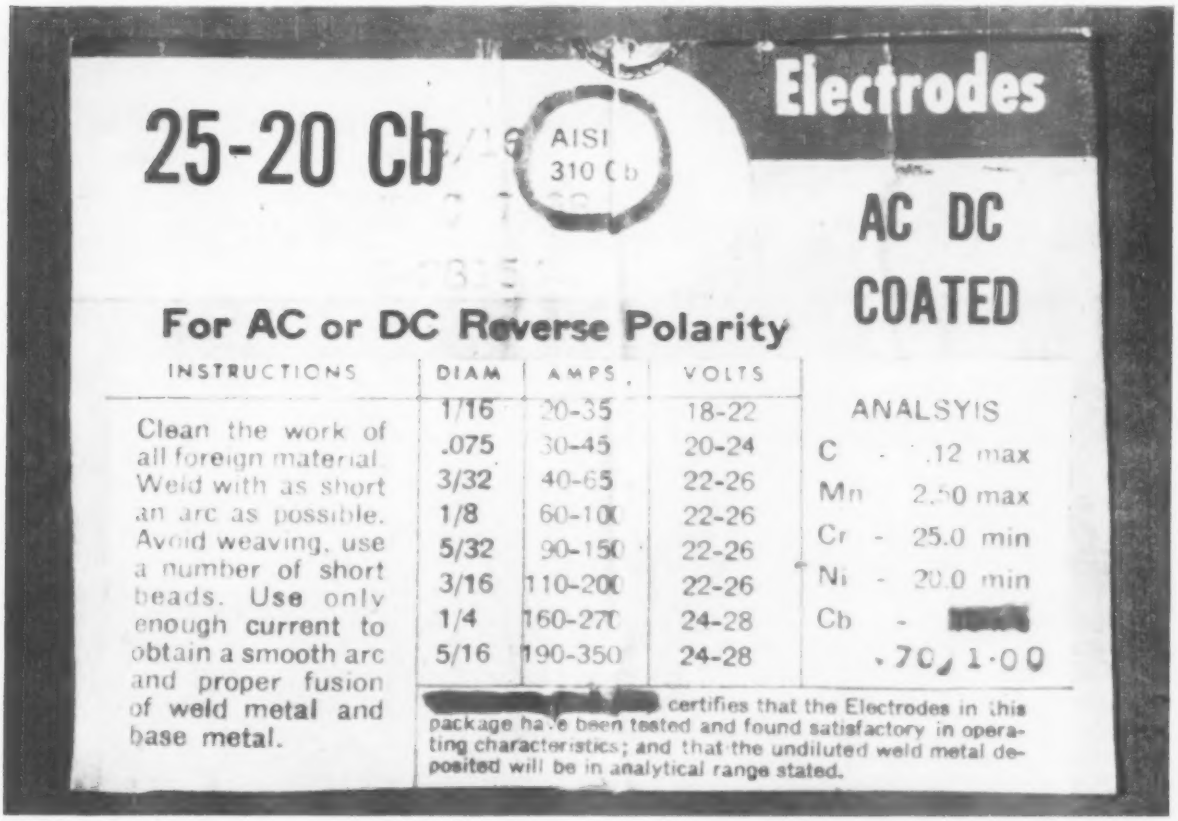

25-20 Cb
AISI
310 Cb
Electrodes
AC DC
COATED
For AC or DC Reverse Polarity
INSTRUCTIONS
Clean the work of all foreign material. Weld with as short an arc as possible. Avoid weaving, use a number of short beads. Use only enough current to obtain a smooth arc and proper fusion of weld metal and base metal.
DIAM
AMPS
VOLTS
1/16 20-35 18-22
.075 30-45 20-24
3/32 40-65 22-26
1/8 60-100 22-26
5/32 90-150 22-26
3/16 110-200 22-26
1/4 160-270 24-28
5/16 190-350 24-28
ANALSYIS
C - .12 max
Mn 2.50 max
Cr - 25.0 min
Ni - 20.0 min
Cb -
.70/1.00
certifies that the Electrodes in this package have been tested and found satisfactory in operating characteristics; and that the undiluted weld metal deposited will be in analytical range stated.

Fig. 3 Paper label on electrode container is only identification

welding procedures without deviation and use the electrodes and filler wire specified. They are responsible for proper care of electrodes while in the production areas. Welders are only to take the amount of electrodes which can be used immediately.

## Summary

Since customers of alloy equipment are demanding more stringent controls via mill test reports on material chemistry, weld deposit corrosion coupons, lot numbers of electrodes, etc., it is imperative that a program of this kind be given serious consideration by all alloy equipment fabricators.

The advantages that can be enjoyed with an effective electrode control program are as follows:

A. Production personnel will be relieved of the responsibility for stocking electrodes.

B. Production will not "run out" of electrodes and filler wires.

C. An oversupply shall not occur with the running inventory control system.

D. Stock will be fresh.

E. Purchasing Department can buy at quantity discounts.

F. Electrode waste should be materially reduced.

G. Weld quality shall be greatly improved.

H. Customers will recognize good organizational objectives, thereby enhancing customer relationships.

Fig. 4 Identification of electrodes imprinted on container

*Acknowledgment*

The author wishes to express his appreciation to The Colonial Iron Works Co. for permission to present this paper.

# GAS-SHIELDED METAL-ARC SPOT WELDING ON TURBINE COMPONENTS

*Adaptation of gas-shielded metal-arc process saves thousands of dollars at turbine manufacturer's plant*

BY LOU AMES

High speed plus the deep penetration necessary on thicker metals has now been brought to spot welding by the gas-shielded metal-arc process. This has been accomplished by adapting manual equipment with a special nozzle and a timing device which automatically controls a 3 second weld cycle (Fig. 1). What this new spot-welding operation means in time and dollar savings can be seen from the application of the process at the S. Morgan Smith Co., York, Pa.

Harnessing water power has been the business of this company since 1876 when its founder, Stephen Morgan Smith, designed an improved water wheel to turn a grist mill. Since then they have built more than 9500 hydraulic turbines with a total capacity of over 15,400,000 hp.

Among the largest turbines ever built are 14 turbines

**Lou Ames** is Technical Representative, Air Reduction Sales Co., Philadelphia District.

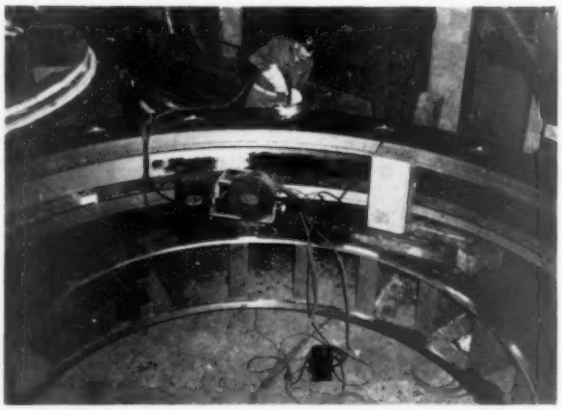


Fig. 2 Stainless-steel circular plate is locked to mild-steel substructure of hydraulic turbine with stainless-steel locking screws reinforced by gas-shielded metal-arc spot welds

Fig. 1 Close-up of adapter nozzle which converts manual equipment for spot welding

Fig. 3 Spot welding in action—time saved 44 hr on each turbine

for the hydroelectric project at the McNary Dam on the Columbia River. Each turbine is 100 ft high and weighs 1000 tons. Working in giant sizes with high precision requires special facilities and the highest efficiency of processes. Also, on such large scale products, time savings on a single operation can easily mount into thousands of dollars. Such savings were effected by the company through the use of spot welding in the production of hydraulic turbines.

The spot welding shown here is done on the head of a stainless-steel locking screw (Fig. 2). Hundreds of these screws are required to hold a heavy stainless-steel circular plate to the mild-steel substructure of a hydraulic turbine. Fastening the rings in this manner allows the large plate to be removed easily after substantial service wear.

The spot welds reinforce the locking screws. Close to a thousand spot welds with $^5/_{16}$ -in. to $^3/_8$-in. penetration are made on turbines of the size in these pictures. The speed and efficiency of the operation exceeded expectations. With the previous method—drilling a small tapered hole and then welding with stick electrode—it took 25 hr on each head cover or bottom ring. With spot welding, the time was reduced to only 3 hr. Therefore, on each turbine the company saves 44 hours with this spot-welding process (Fig. 3). At their present production rate this runs into thousands of dollars saved a year.

Thus this newest development of the gas-shielded metal-arc process and equipment offers new speed and economy to meet the ever-increasing need of spot welding on thicker materials.

# $CO_2$ PROCESS HANDLES AUTOMATIC WELDING OF REAR-AXLE HOUSINGS

The carbon-dioxide welding process has been given a major role in parts production for Ford Motor Co.'s 1957 models. As applied to Ford operations it is used for welding components of rear axle housings—banjo, banjo cover and flanges—into integral units. It is thought to be the first application of the $CO_2$ welding process to a full-scale, highly-automated line.

In the $CO_2$ process, the powdered flux of the submerged-arc process is superseded by a jet of $CO_2$ that forces normal atmosphere away from the weld area. Major advantages are brought about by elimination of flux. Welding speeds are increased, materials costs are from 10 to 25% lower, and maintenance and materials handling costs are reduced. Also, side delivery of $CO_2$ extends the time the equipment can be operated before nozzle cleaning is necessary.

Production engineers find high welding speeds reduce floor time for welding operations by about 32%. In production welding the differential cover to the housing, the $CO_2$ process permits speeds of 140 ipm. Total time required for the operation is 28 sec, rather than 39. Equipment at one plant will include 71 welding heads on 31 automatic welding fixtures.

Based on a story by Westinghouse Electric Corp., Pittsburgh, Pa.

Fig. 1 Carbon-dioxide welding process gets a major assignment. At a Ford plant, rear axle housings for 1957 models are welded at speeds up to 140 ipm

Electrical equipment includes a 600-amp, constant-potential power source of the rectifier type. The power source can be remotely controlled and has automatic compensation for limiting variations in output voltage to 0.5 volt.

# SPEEDING PRODUCTION OF ALUMINUM OIL TANKS

*Inert-gas-shielded metal-arc process used to build leakproof tank trucks*

At the Heil Co. of Milwaukee, Wis., the quality of the weld is extra critical—just as important as the material being welded. Above all, no weld leakage is permissible.

This is one of the many reasons why both management and operating personnel for this leading manufacturer of aluminum tank trucks are using automatic and semiautomatic consumable-electrode inert-gas-shielded metal-arc welding equipment (Fig. 1).

The efficient production of aluminum transport tanks presented problems that were solved only when this type equipment was put on the line.

For instance, at one point during the production, the welders must crawl through small manholes in the tank and make full lap welds 10 to 11 ft long, vertical and horizontal, between the heads and the belly sections. The automatic current regulation and constant arc length features of the welding machines enable the welder to adjust the generator once, without having to crawl in and out of tank as often.

Savings in time, plus less rewelding due to fewer

Based on a story by the General Electric Co., Schenectady, N. Y.

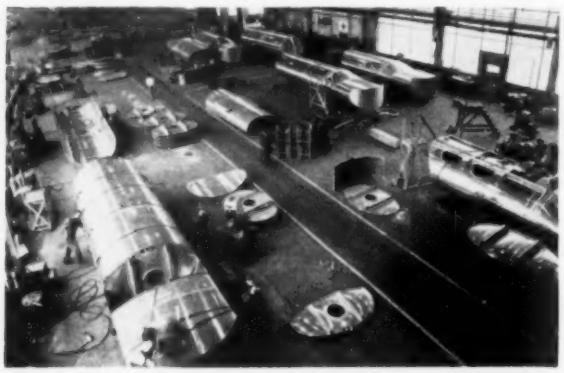


Fig. 1 Over-all view of the assembly floor at the Heil Co. where aluminum transport tanks are produced

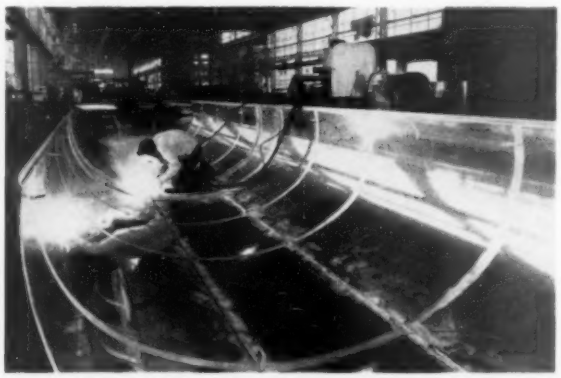


Fig. 3 Butt joints being welded to form shell of tank

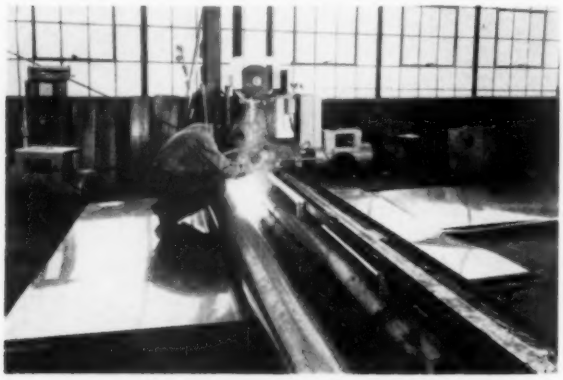


Fig. 2 Automatic inert-gas metal-arc welding of aluminum sheets. Later these will become outer shell of tank

Fig. 4 Compartment separators being welded before cover is welded in place

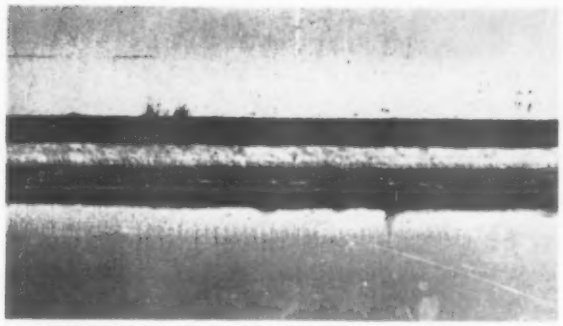


Fig. 5 Straight lap weld made by automatic inert-gas-shielded metal-arc welding

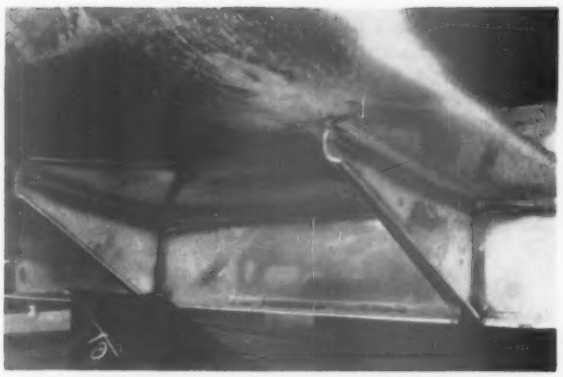


Fig. 6 Inert-gas metal-arc weld on butt joint support at bottom of tank

rejects, have increased the company's production by $^{3}/_{4}$ tank a day—a 35% increase.

## Production Cycle, Step by Step

The complex trailer assembly starts with an automatic process (Fig. 2). Two sheets are butt welded in an automatic operation that produces a uniform weld up to 14 ft long, joining the metal into a single piece that will be rolled into the belly of the tank.

Then, four sheets are butt welded by manual semiautomatic welding machines into two sheets which will form the upper shell of the tank (Fig. 3). The beads are up to $4^{1}/_{2}$ ft long and are welded in a flat position.

Then the actual assembly begins. The tank is positioned on its back and the two halves of the upper shell are lap welded onto a 32-ft long catwalk.

Next, heads are set in place on the upper shell. These are formed in a strong, triple-dished shape. Two strengthening flanges are fillet-skip welded horizontally on the plates. Manholes are cut in some of the heads and a ring is fillet welded around the holes.

The heads are then attached to the shell by lap welds (Fig. 4). The compartment heads are fully welded, but the heads inside the large compartment are skip welded. Some of the beads here run as long as 10 ft.

With the heads in place, the belly sections are laid in place and tightened with metal bands. The sheets are tacked with an inert-gas tungsten-arc welding machine.

A throat section is then lap welded on and the longitudinal seam between the belly and the upper shell section is lap welded (Fig. 5). These beads are up to 32 ft long.

Wheel pockets are inserted next using fillet and butt welds, and then the 20-ft supporting members of the belly of the tank are fillet welded from a horizontal position (Fig. 6).

The tank is then turned right side up and the finishing touches are applied. This is the point where the welders must crawl through the small manhole described earlier.

The finished tanks (Fig. 7) have capacities running from 3000 to 9000 gallons and are as long as 32 ft in length. The tank shell is made of 0.156-in. aluminum alloy 5154. Tank heads are formed hydraulically

Fig. 7 Finished product—a petroleum truck tank

from 0.186 aluminum blanks of the same alloy. The long supporting members that attach the running gear to the tank proper are preformed from 0.250-in. aluminum. Flawless, leakproof welding is needed to turn aluminum sheeting into a tank that will provide 34,000-lb per sq in. tensile strength, and the manufacturer finds that this type equipment does the job.

## 13 Units Do the Job

Heil uses 13 rising volt-ampere generators in the tank division and eight semiautomatic wire drives and torch units, and one completely automatic welding machine.

To extend the mobility of the semiautomatic equipment, the company mounts the wire drive unit, tank of argon shielding gas, plus source of cooling water for torch, on a steel cart. Thus, the power supply is the only external connection required by the unit.

## Tests

Strict tests are given the welds at Heil. The tanks are first given a dye solution test in the catwalk and wheel pocket areas to assure leakproof welds. The tank is then given an over-all inspection. Porosity-free welds, with no undercuts, are a must. Then a final pressure oil test is given before an O.K. is stamped on the finished product.

# WELDING—KEY TO EXPOSED STEEL-FRAME BUILDING

By WILLIAM BROOKS

A food store, the Penn Fruit Co., in the Philadelphia area (Cynwyd, Pa.) uses a 130-ft welded rigid-frame span, with the rigid frame exposed to obtain clean appearance and unobstructed area.

The building frame consists of six welded rigid frames spaced 21 ft 8 in. with a height at the center of 24 ft. Between the frames are 12-in. steel purlins that carry tees, which, in turn, support a 3-in. gypsum slab roof. Since the architects wanted to get the exposed steel effect, neither the inside nor the outside flanges of the legs of the rigid frames were incased in the exterior walls and, in addition, the lower halves of the girders are allowed to project below the plaster ceiling—to give a smart styling effect.

Several problems were encountered in the building. To enhance the over-all appearance, it was desirable to have the inside flanges of the legs and the bottom flange of the girder of each frame be continuous in a smooth curve. This, however, created a problem, since calculations called for a 36-in. wide flange section for the girder, while, for space purposes only, a 30-in. section was wanted for the legs. The flanges of these two rolled sections had different widths. This situation was solved by using 36 WF 194 sections for both girder and legs, but cutting back the leg to 30 in. and by replacing the inside flange with a 12- x $1^1/_2$-in. plate.

A curve of the 8-ft 6-in. radius serves as the transition from the legs to the girder, which is formed of two 36 WF 194 sections inclined 1 in. per ft to a ridge at the center where the sections are joined by a field weld made with an E-6010 electrode. The curved flange had to be prevented from buckling, so the web plate of the knee was made of 1 in. thick and three sets of triangular stiffeners, 3 x 4 x $^1/_2$ in., were put in strategic points along the curve of the flange.

Rigidity of the frame, braces and web stiffeners was assured by putting a single horizontal stiffener high enough on the web of the knee, so it would be hidden by the ceiling and also extending it into the web of the girder. Additional rigidity was further assured by welding brackets under the two purlins that join the frame near the knee, thus deepening their connections.

The load of 98,500 lb for each frame is resisted by two tie-rods under the floor (Fig. 1). These $1^3/_8$-in. rods have an upset of $2^1/_4$ in. diam at the tread end. But there were no shops in the vicinity that could upset the rods, so the treaded ends of the required size were welded on. Before welding, the rods were ground to a 60° bevel. The rods were coated with pitch and set in sand in a concrete trench to allow for elongation.

**William Brooks** is Welding Engineer, the Lincoln Electric Co., Philadelphia, Pa.

Fig. 1 Bracing for rigid frames is placed so that it will not be visible as part of the steel which is left exposed for architectural effect

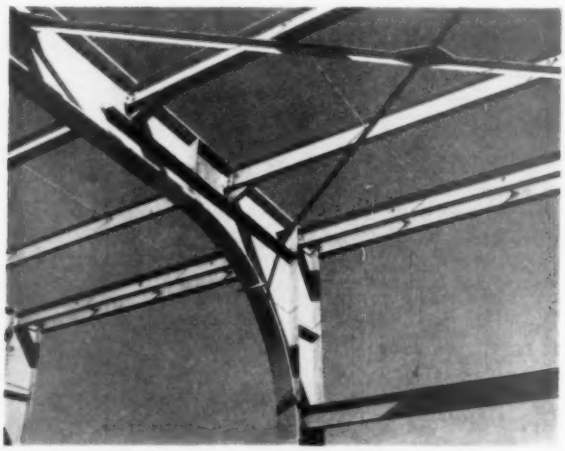


Fig. 2 Detail of knee section of 130-ft rigid frame

Shop fabrication employed $^1/_4$-in., E-6024 electrodes on fillet welds. Speeds of 14 ipm netted 30% savings.

The weight of each frame was about 22 tons. The calculated elongation of the tie-rods under maximum live load was 0.54 in.

Each of the six rigid frames was erected in four sections—two sections of the overhead girder plus the two leg-and-knee sections. Welded field splices were located at the top tangent of the knee and at the centerline of the building (Fig. 2).

Two 15-ton cranes were used to lift the erection for the setting legs, and these were joined with the foundations and the overhanging knee. Then the two halves of the top girders were put in place with ends of the building centerline and supported on a steel shore—an 8 WF 31. Several purlins were put in place for bracing and field splices tack welded.

The knee sections were fabricated using E-6024 and E-6012 electrodes. Fillet welds in these sections were mostly $^{3}/_{8}$-in. and $^{1}/_{2}$-in. gage sizes, the multiple welds being made at a speed of 14 ipm on the individual passes. A $^{1}/_{4}$-in. size E-6024 electrode was used with an estimated saving of 30% over using an E-6012 electrode.

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# TUNGSTEN-ARC WELDING LICKS ALUMINUM TROUBLES

Fusion welding of aluminum parts often proves difficult even for the veteran welder. Harry Thommen Co. Inc. of Bridgeport, Connecticut, realized this when they recently accepted the job of welding an all-aluminum chart table for one of Uncle Sam's modern aircraft carriers. They also knew, however, that welding aluminum is no longer the problem that it once was—thanks to the argon shielded arc.

The component parts of the table, consisting of two leg sections and the table top, were formed from 53S aluminum alloys, approximately $^{5}/_{16}$ in. thick. All sections to be welded were veed to a 60 degree angle. Two passes were made, as recommended for inert-gas tungsten-arc welding of most materials over $^{1}/_{4}$ in. in thickness. The first pass was a "root weld" to provide complete fusion to the bottom of the joint (Fig. 1). Then a second pass was made to complete the joint. A $^{5}/_{32}$ in., two percent thoriated-tungsten electrode was used with 350 amp alternating current, high-frequency. Filler rod used was the same as the base material.

After the welding was completed (see Fig. 2), the table was heat treated to relieve stresses.

Based on a story by the Linde Company, New York, N. Y.

Fig. 1 This operator is nearing completion of the "root weld." He is using an argon flow of 20 cu ft per hr

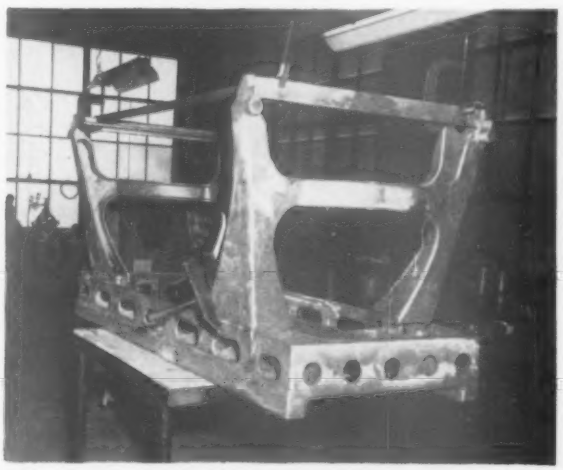

Fig. 2 This table is soon to see service aboard one of our Navy's aircraft carriers. Notice how its parts are clamped in place to assure proper spacing of edges to be welded

# SCRAPPING FOR POWER

BY J. M. HELLER

Back of the New York subways, as they rumble underground carrying their daily load of millions of people, stands the powerhouse . . . vital to the operation of this vast transportation system. To maintain peak performance is crucial—and old generators must give way to the new.

At the IRT Powerhouse, 59th Street and 11th Avenue, New York, nine huge generators—erected in 1902 and having served their purpose well—are now being dismantled for an improved power installation (Fig. 1).

Lipsett, Inc., New York, heavy demolition specialists, are doing this work which will produce thousands of tons of scrap steel. Some of the steel sections cut free and hauled away on low boy trailers weigh 45 tons.

To dismantle these giant generators, heavy-duty oxyacetylene cutting equipment is used (Figs. 2 & 3). Designed for hard, grueling work on heavy jobs, cutting torches easily handle maximum thicknesses of 38 in. on this job. Built up steel laminations 24 in. thick, with mica sheeting sandwiched between each lamination, are also encountered and cut through with ease.

The supply and gas distribution system on this job involves the use of an oxygen trailer, along with a portable control panel for pressure reduction and control (Fig. 4). One inch diam hose from the control panel to a six outlet header supplies six cutting operators. Acetylene requirements are taken care of by manifolding 12 acetylene cylinders. This system is

J. M. Heller is Technical Representative, Air Reduction Sales Co., Metropolitan District.

Fig. 1 IRT Powerhouse generators being scrapped

Fig. 2 Oxygen cutting of generator

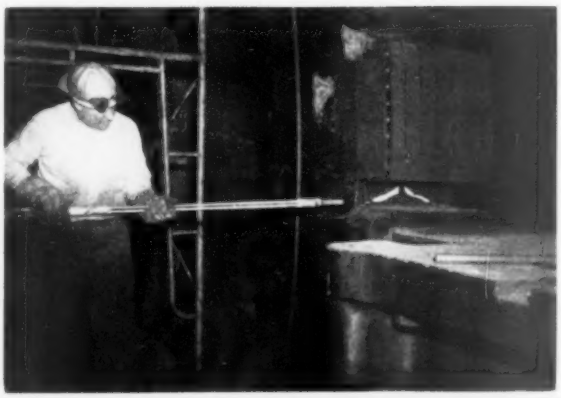

Fig. 3 Heavy-duty cutting torch, ideal for hard, grueling work, ready to slice through huge generator parts

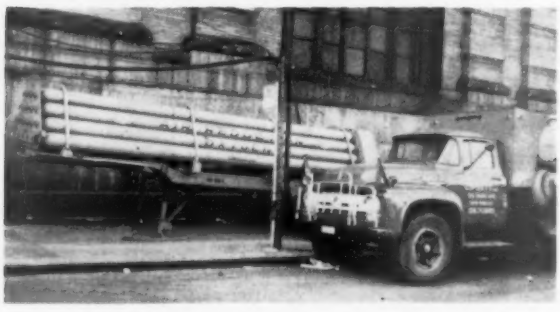

Fig. 4 Gas distribution system at IRT Powerhouse, showing oxygen trailer

protected by hydraulic flash arrester units and additional safety factors. The acetylene gas is transferred from the manifold through one-inch diam hose to a six outlet acetylene header.

In the power generating field, as in many others, rapid technological progress means equally rapid obsolescence, and oxygen-cutting techniques like this make heavy steel demolition safer, more efficient and economical. Scrap is salvaged for new steel and the way cleared for ever better equipment.

# TRIPLE LIFE THROUGH HARD SURFACING FOR REFINERY CATALYST UNIT COMPONENT

A Texas refinery anticipates three times the service life from a stem tube it has hard-surfaced with a nickel base alloy containing chromium borides. The component operates in a Kellog Ortho flow converter fluid catalyst unit. It actuates an 18-in. Wallworth plug valve.

The plug valve is attached to one end of the stem tube; the valve stem is attached to the other. When opening and closing the valve, the stem tube moves in two chrome-cobalt-tungsten castings that are pressed into the guide liner. The castings are 12 in. in diam by $3^1/_4$-in. long.

Original stem tubes for the unit are chrome plated. Standard practice is to turn them around once a year for more even distribution of wear. On the first turnaround at the subject refinery in Texas, erosion was so extensive as to prohibit placing the part back in service.

To increase part life and thereby reduce maintenance costs, the replacement stem tube was surfaced over an area 5 ft by 6 in. long on the 12-in. OD of the tube. The material used is a nickel-base hard-surfacing alloy containing chromium borides; it possesses high abrasion, corrosion, impact and galling resistance and an unusually low coefficient of friction.

In the surfacing procedure used the hard-surfacing alloy in powder form is applied with a special pistol to the base metal of the part. The mechanically bonded powder is then welded to the base metal by application of an oxyacetylene torch flame as the part is rotated in a lathe. It is then ground to provide a proper surface for installation of packing. Following finish grinding, the stem tube is ready for installation.

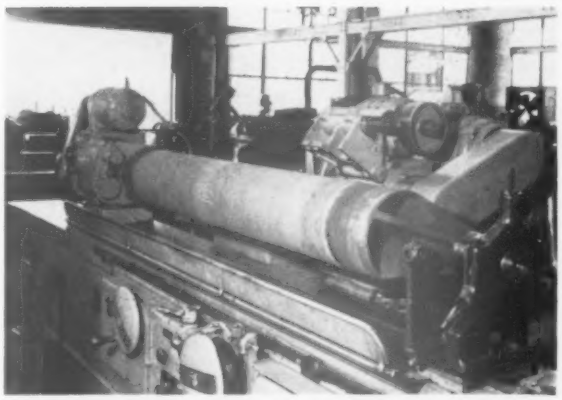

Fig. 1 Stem tube with fusion bonded overlay of hard-surfacing alloy before grinding

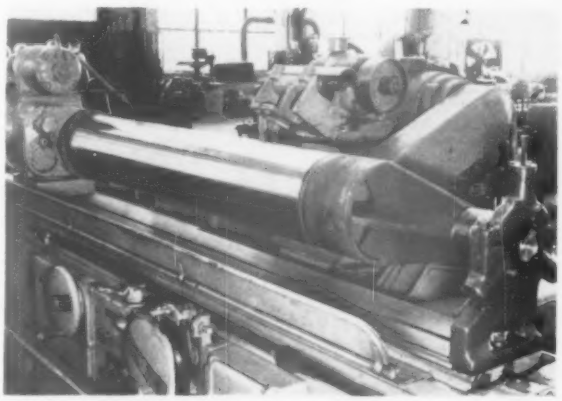

Fig. 2 Finish-ground part ready for catalyst unit installation. Note highly polished surface achieved which contributes to reduced packing wear. Low coefficient of friction remains relatively constant even after part has been a long time in service

Based on a story by the Wall Colmonoy Corp., Detroit, Mich.

# AUTOMATIC WELDING OF ALUMINUM FUEL TANKS FOR ROCKET-PROPELLED MISSILES

BY J. R. McFARLAND AND HAROLD DAVIS

In the fabrication of aluminum fuel tanks for rocket-propelled missiles, Hayes Aircraft Co., Birmingham, Ala., doubled production speed by a change-over from manual to fully automatic welding operations with the inert-gas-shielded tungsten-arc process (Fig. 1).

Tanks made on this important government project called for two circumferential lap welds on 52S aluminum, 0.091 in. thick. Specifications required that the weld—approximately 56 in. in circumference—should not exceed a width of 0.250 in. (Fig. 2). In addition filler-wire deposition should not be more than 0.015 in. above the top surface, and penetration of the weld should be between 80 and 100%. These tanks are subjected to a hydrostatic test of 40 psi for 10 min, which is then followed by an air test of 10 psi.

Manual welding operations required as much as 18 min to complete two circumferential welds. When the manufacturer went to a fully automatic setup, complete handling and welding of a tank required less than 10 min.

The new installation involves the use of a welding head with filler-wire feeder. To obtain proper weld technique, the welding head was positioned approximately six degrees off the vertical plane with the weld being made at 12 o'clock in relation to the rotation of the tank. Filler-wire feeder is located directly to the rear of the operation to allow a straight run for the wire, and the wire guide is positioned approximately 21 degrees off the horizontal plane. Welding speed is 15 ipm with 50 cfh argon shielding, and $^{1}/_{16}$-in. diam 54S filler wire is used at 110 ipm (Fig. 3).

In addition to increased production speed, Hayes obtained consistently excellent weld results because of the full control of adjustment factors made possible with a fully automatic welding installation.

J. R. **McFarland** is Technical Representative, Air Reduction Sales Co., Birmingham District, and **Harold Davis** is Process Engineer, Air Reduction Sales Co., New York, N. Y.

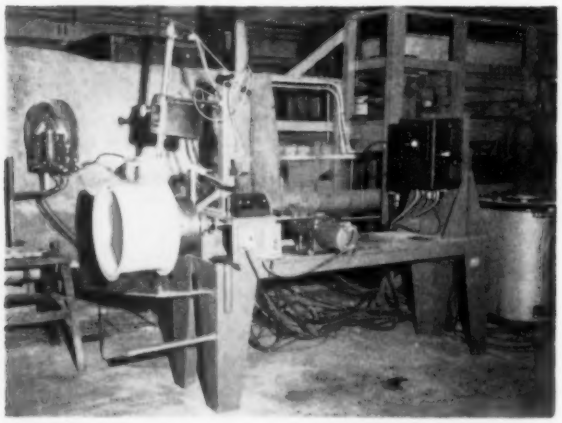

Fig. 1 Complete view of automatic welding installation for circumferential welds on aluminum fuel tanks for rocket-propelled missiles. Welds had to be made to critical specifications

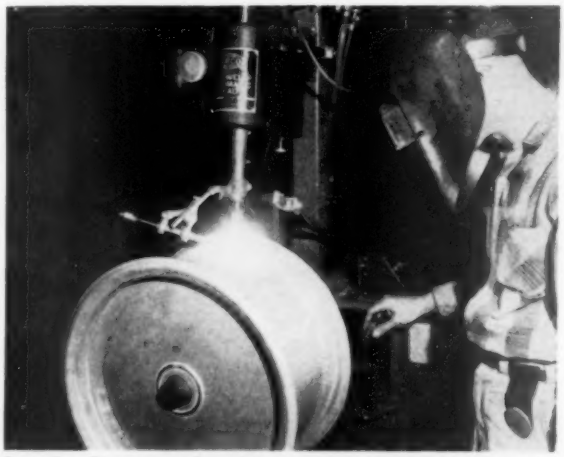

Fig. 2 Close-up of welding operation. Circumferential lap welds made on 52S aluminum, 0.091 in. thick. Weld 56 in. in circumference could not exceed 0.250-in. width

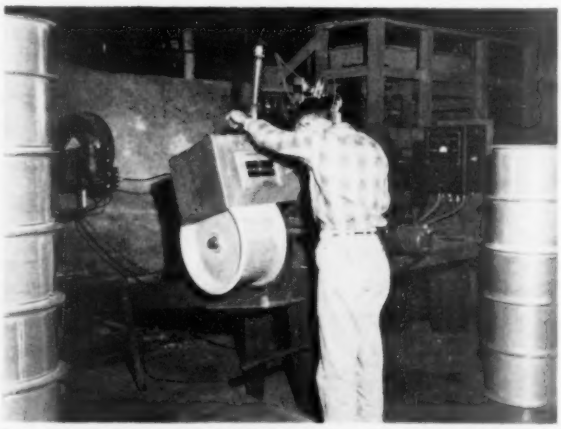

Fig. 3 Automatic welding speed is 15 ipm. Automatic installation doubled production speed over former manual operation

# TRACTOR COMPANY WELDS GALVANIZED IRON WITH ALUMINUM BRONZE

BY C. V. KENNEY

At Caterpillar Tractor Co., one of the world's largest and most renowned builders of tract-type tractors, diesel power units, hauling scrapers, road graders and other types of earth moving equipment, quality standards must be exceptionally high due to the severe service conditions encountered in the use of their products.

In fact, this company invests thousands of dollars annually in welding research to find better materials and develop better methods of fabricating their products, as well as in plant maintenance and repair.

After extensive welding and corrosion testing, ECuAl-A2 electrodes were selected by Caterpillar welding engineers to fabricate the galvanized hood and piping shown in Figs. 1 and 2.

Both hood and piping in this exhaust system and exposed stacks were fabricated from 16-gage galvanized sheet using $^{3}/_{32}$-in. diam ECuAl-A2 electrodes with reverse polarity, direct current and the metal-arc process, saving 30% on welding time over former methods used for similar fabrications made in the past.

To determine corrosion resistance of the galvanized steel welded with ECuAl-A2 electrodes, several 16-gage galvanized steel samples were welded and placed in a container (as shown) with a strong salt brine composed of one part salt and five parts water (Fig. 3). This brine solution was allowed to creep by capillary action over the entire plate and weld area for 100 days, during which time periodical observations were made to determine effect. The weld area was affected by corrosion at about the same time and to the same extent as the nonheated part of the test plates.

ECuAl-A2 electrode was selected for use in welding galvanized sheet because: (1) it can be applied at a faster rate of travel burning away less galvanizing at the joint; (2) it produces sound welds that are watertight; (3) it resists corrosion; (4) it can be applied with a minimum of joint preparation; (5) the beads are smooth with uniform penetration; and (6) the deposit mechanical properties are comparable to those of the base metal.

C. V. Kenney is associated with Machinery & Welder Corp.

All photos courtesy of Ampco Metal, Inc., Milwaukee, Wis.

Fig. 2 16-gage galvanized steel ducts fabricated with ECuAl-A2 electrode

Fig. 1 Large galvanized steel hood after welding

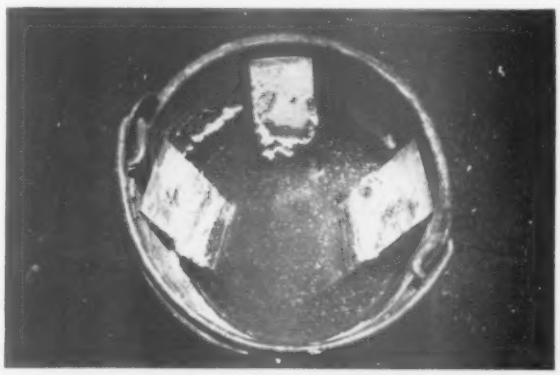

Fig. 3 Welded specimens tested in brine solution

# STANDARDIZED BRACES AND CORNERS DESIGNED TO IMPROVE APPEARANCE OF WELDMENTS

Modern weldments can easily be designed to appeal to the esthetics of the curve and smooth-flowing line. Economy of fabrication in these designs, however, may not always be so easily obtained.

Looking at this problem, the Conner Steel Products Co., Detroit, decided something should be done about it. They interviewed scores of fabricators throughout the country and found some agreement on the problem of fabricating welded assemblies for good appearance.

They concluded, as one result of this product research effort, that two or three simple, geometrical shapes, formed to precision dimensions and sold at moderate cost, might offer builders of weldments a means of economizing in their efforts to "smooth up" their designs. Thus far, they have originated U-braces, pyramid or V-shaped braces and spherical corners to fit such requirements. They are supplied in mild steel, stainless steel and aluminum alloys. Accompanying illustrations show various sizes and how they are installed (Figs. 1 to 4).

Spherical corners, for example, are available in thicknesses of 18 to 10 gage and radii ranging from $^1/_2$ to 3 in. So-called U-shaped braces may be obtained from $^1/_2$-in. width by 2-in. angle side to 1-in. width and 6-in. angle—these for right angle bracing and in thicknesses of $^3/_{32}$, $^1/_8$ and $^3/_{16}$ in.

Stronger corner braces, because of their lateral flaring from the 45° hypotenuse are the pyramid or V-type, precision formed and finished in thicknesses of $^1/_8$, $^3/_{16}$ and $^1/_4$ in.

Based on an award-winning paper in a recent design competition sponsored by The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

Fig. 1 Assorted sizes of U-shaped and pyramid or V-shaped corner braces, with a line of spherical corners between them, are designed as an aid to better appearing weldments

Fig. 2 Installation of a typical pyramid corner brace on an angle frame. By flaring the sides, additional lateral support is provided to the 45° hypotenuse of the piece

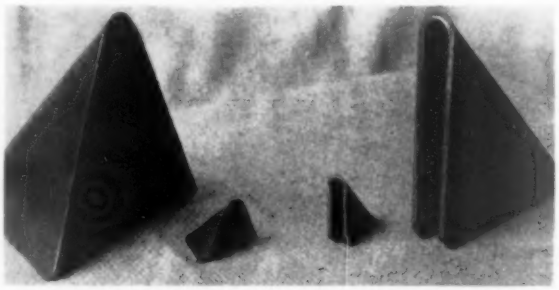

Fig. 3 Being precision formed and finished, these large and small corner braces make full contact with the frame members to which they are welded, with resultant maximum strengthening

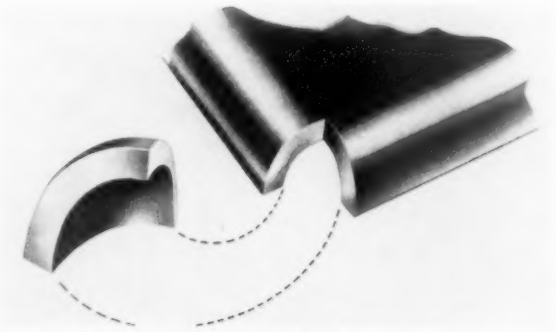

Fig. 4 How a standardized spherical corner is fitted into a notched and bent plate of a typical machine base or pan to improve the over-all streamlined appearance

Fig. 1 Longitudinal welds of doubler plates to the main legs of offshore oil drilling platforms are made by two mechanized submerged-arc welding heads mounted on carriages

Fig. 2 An operator using a tungsten-arc torch makes a longitudinal butt weld in a wrapping of Monel alloy for carbon steel pipe. No postweld cleaning is necessary for this operation

# WELDING TREASURE ISLANDS

Man's quest for the black gold cached by nature beneath the Gulf of Mexico led to the development of a new industry—the building of huge offshore oil drilling platforms. These vital man-made islands, often as high as eight story buildings and weighing from 250 to 1200 tons, are set in water 35 to 90 ft deep and are located as far as 35 miles from shore.

Pounding waves and salt water corrosion have presented special problems in the construction of these platforms. Reinforcement of key areas is essential. Weld quality is important.

Dupont Fabricators, Inc., Morgan City, La., a pioneer builder of these structures, saved hundreds of man-hours and increased weld quality of the platforms by using manual tungsten-arc argon-shielded and mechanized submerged-arc welding to replace former welding methods.

Rapid corrosion of the steel legs at the splash zone—the area where waves hit the legs—was a major problem. Sheets of 20-gage Monel alloy or copper are now used to provide additional protection for the carbon steel pipe. Longitudinal butt welds and circumferential fillet welds of these wrappings are made by manual tungsten-arc argon-shielded welding. This builder selected this welding process because it is fast and post-weld cleaning is eliminated.

Man-hour savings in welding of doubler plates to the main structure legs is made possible by mechanized submerged-arc welding. These plates reinforce the legs at points where horizontal and diagonal braces meet. Now, with this welding process, it takes one operator one day to complete a job which previously required five men.

Several hundred man-hours also were saved by mechanized submerged-arc welding of multiple joints in piling, which usually consists of four or five lengths of 33-in. diam pipe.

Based on a story by the Linde Company, New York, N. Y.

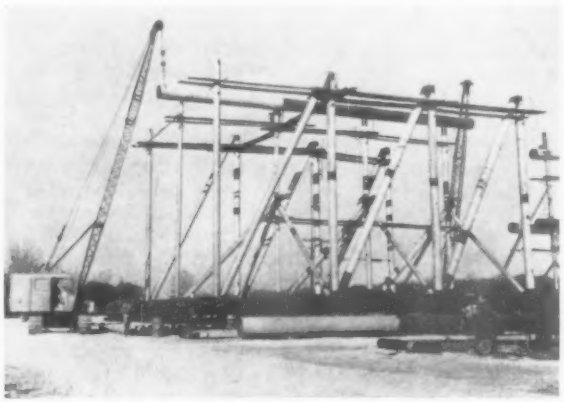

Fig. 3 This is one section of an offshore oil drilling platform in the process of being built

Fig. 4 Wrappings of 20-gage Monel alloy may be seen at the splash zone of this offshore oil drilling platform located in the Gulf of Mexico

# Society News

## Greenberg Joins Westinghouse, Fenton Appointed Technical Secretary

Simon A. Greenberg

Edward A. Fenton

Effective June 1, 1957, Simon A. Greenberg became associated with the Atomic Power Division of Westinghouse Electric Corp. in Large, Pa., thereby relinquishing his position as technical secretary of AWS, a post he had held for ten years.

Mr. Greenberg is a graduate of Brooklyn Polytechnic Institute. His subsequent experience included welding inspection, qualification and design with the Brooklyn and Philadelphia Navy Yards and with private industry.

He was made Assistant Technical Secretary in 1942 and later Acting Technical Secretary. Mr. Greenberg was appointed Technical Secretary in 1947 and, at the same time, assumed the editorship of the 3rd Edition of the WELDING HANDBOOK.

Edward A. Fenton has been appointed technical secretary to replace Mr. Greenberg.

Mr. Fenton, who joined the SOCIETY staff in 1954 as assistant to the technical secretary, was promoted to assistant technical secretary on Jan. 1, 1957.

He attended the College of the City of New York and graduated in 1947 with a degree of Bachelor of Mechanical Engineering. He later attended the Polytechnic Institute of Brooklyn and received the degree of Master of Metallurgical Engineering.

From 1947 to 1954, Mr. Fenton held positions of a welding and metallurgical nature in the shipbuilding, railroad, oil refinery, chemical plant and jet engine industries.

He is a member of the AMERICAN WELDING SOCIETY, American Society for Metals, Sigma Xi and is a registered professional engineer in the State of New York.

### Seven Supporting Companies from New England

Supporting Company Member enrollment applications have been received from six organizations, all located in Rhode Island: B-I-F Industries, Inc., 345 Harris Ave., Providence; Corp Brothers, Inc., 1 Brook St., Providence; Cranston Welding & Supply Co., 1425 Park Ave., Cranston; G. H. Wood & Son, 22 Manson Ave., Norwood; Rhode Island Welding Supply Co., Inc., 561 S. Main St., Providence; Rumford Steel Products, Inc., 200 Point St., Providence. All these enrollments became effective on July 1st.

Still another Supporting Company enrollment is the A. F. Robinson Boiler Works, 200 2nd St., Cambridge 42, Mass.

### Asiatic Petroleum New Sustaining Member

Asiatic Petroleum Corp. with main offices at 50 W. 50th St. in New York City, has assumed Sustaining Membership in the AMERICAN WELDING SOCIETY. Mr. S. J. Veenstra will be the Sustaining Member Representative.

### Chicago, Burlington & Quincy R. R. New Sustaining Member

The Chicago, Burlington & Quincy Railroad of Aurora, Ill., joins the expanding list of companies with sustaining memberships in the AMERICAN WELDING SOCIETY.

Its important function in passenger and freight transportation necessitates the company to use many types of

### District 1 to Hold Welding Conference

On Sept. 18, 1957, all sections within District 1 of the AMERICAN WELDING SOCIETY will sponsor the Second Annual New England Conference on Welding at New England Mutual Hall in Boston, Mass. The Boston Section will act as host.

Tentative plans include morning sessions on high-temperature brazing, the welding of stainless steel and welding for nuclear reactors. A social hour and banquet in the early evening will be preceded by afternoon sessions on automatic welding, tool steel and magnetic force welding.

Any inquiries for reservations or information should be directed to Allan Rosenberg, General Electric Co., A. A. T. Dept., 920 Western Ave., Lynn, Mass.

welding in connection with maintenance and repair of locomotives, freight and passenger cars, track equipment and structures, as well as construction of freight cars.

The Sustaining Member representative is R. A. Boerke.

## Detroit Edison Becomes Sustaining Member

The Detroit Edison Co., 2000 Second Ave., Detroit 26, Mich., has become a Sustaining Member of the AMERICAN WELDING SOCIETY.

Detroit Edison supplies residential, commercial and industrial electric-power requirements in a 7600-sq mile Southeastern Michigan area with a population of more than 4 million. Including metropolitan Detroit, the service area has 63 cities, 76 incorporated villages and some 254 unincorporated communities. The company owns and operates 6 large steam-electric and 5 small hydroelectric power plants with total capability of 2,841,000 kw. Electric service is provided to 1,192,000 customers. The company also owns and operates 4 large central steam-heating plants which serve 1760 commercial and industrial customers in Detroit.

The Sustaining Member representative is E. G. Shifrin.

## Great Northern Railway Assumes Sustaining Membership

The Great Northern Railway Co. of St. Paul, Minn., has become a sustaining member in the AMERICAN WELDING SOCIETY.

Great Northern Railway is an 8250-mile system serving ten Northwest states between Lake Superior and the Pacific Ocean, and two provinces in Canada.

Forerunner of Great Northern was the St. Paul & Pacific, first railway in Minnesota. This line was acquired in 1878 by James J. Hill and associates, and gradually expanded into the present system. With Northern Pacific the Great Northern controls the Burlington system, and shares ownership of the Spokane, Portland & Seattle Railway.

J. L. Robson is the Sustaining Member representative.

## C. B. Smith Appointed National Membership Chairman

At the June 4th meeting of the board of directors of the AMERICAN WELDING SOCIETY in New York City, C. B. Smith was appointed national membership chairman.

C. B. Smith

Mr. Smith is a licensed engineer in the State of California and is employed by the Long Beach Division of Douglas Aircraft, Inc. as assistant chief of materials and process engineer. Active in the SOCIETY for 14 years, he recently concluded a successful term as chairman of the Los Angeles Section.

Dear Bonney,

On May 17th last I relinquished the office of Technical Secretary of our SOCIETY. Since coming with the SOCIETY in 1942 I have had occasion to work directly with some of the members and to become acquainted with a rather large number of them. In saying farewell I would like to tell them, through you, how great a pleasure it has been to work with and for them. It seems needless for me to urge them to continue to support the SOCIETY and to take advantage of the many benefits it offers.

My association with the Atomic Power Division of Westinghouse Electric Corp. in Large, Pa. (a suburb of Pittsburgh), I am happy to say, will permit me to maintain contact with many of the friends I have made. I hope each of them will take occasion to at least say "Hello" when they find that they are in the Pittsburgh area.

Sincerest thanks to all of them for a pleasant and gratifying fifteen years and the many wonderful mementos and memories they have provided me. I hope that I have served them well.

My special thanks to you, Bonney, for giving me the space for this note.

Sincerely,

SIMON A. (SI) GREENBERG

## AWS DIRECTORS-AT-LARGE

| Term Expires | 1958 | 1959 | 1960 |
|---|---|---|---|
| | F. H. Dill | J. H. Blankenbuehler | J. F. Deffenbaugh |
| | E. D. Peters | G. E. Linnert | A. E. Pearson |
| | J. L. Wilson | P. G. Parks | C. M. Styer |
| | R. J. Yarrow | F. H. Stevenson | R. M. Wilson, Jr. |

## AWS DISTRICT DIRECTORS

| | |
|---|---|
| *District No. 1•New England* Sidney Low | *District No. 7•West Central* A. F. Chouinard |
| *District No. 2•Middle Eastern* D. B. Howard | *District No. 8•Midwest* F. G. Singleton |
| *District No. 3•North Central* H. E. Miller | *District No. 9•Southwest* P. V. Pennybacker |
| *District No. 4•Southeast* E. C. Miller | *District No. 10•Western* C. L. Breese |
| *District No. 5•East Central* H. E. Schultz | *District No. 11•Northwest* C. B. Robinson |
| *District No. 6•Central* Keith Sheren | |

## OTHER DIRECTORS

| | |
|---|---|
| *Honorary Life Director* C. A. Adams | *Junior Past-President* J. H. Humberstone |
| *Junior Past-President* F. L. Plummer | *Junior Past-President* J. J. Chyle |

# THINGS YOU SHOULD KNOW

• On June 3rd the Finance and Executive Committees of your Board of Directors met at Society Headquarters under the joint chairmanship of Treasurer H. E. Rockefeller and President C. P. Sander. Treasurer Rockefeller submitted a suggested balanced budget with format changed from that of previous years so as to clearly show income and expense, including overhead, for each major group of SOCIETY activities. With minor modifications this budget was approved by both committees and referred to the Board of Directors with recommendation for its approval.

• On June 4th a well attended meeting of your Board of Directors was held at Hotel Commodore in New York with President Sander presiding. The budget covering 1957–58 activities of the SOCIETY was approved as recommended by the Finance and Executive Committees. Treasurer Rockefeller and staff members were extended a special vote of thanks for the excellent presentation of income and expense figures in a logical and easily understood format. At this meeting your Board unanimously approved the appointment of the writer to serve as your National Secretary.

• President Sander submitted his recommendations for appointments of officers and members of our many important standing and special committees for the 1957–58 year. These recommendations were approved. The fact that men of outstanding ability, with the generous support of the companies with which they are associated, are willing to serve the SOCIETY so effectively makes possible the broad and diverse program of activities conducted by your SOCIETY.

• National Membership Chairman C. B. Smith attended the meeting as a guest and discussed plans for promoting membership activities.

• District Director Sidney Low requested approval of a new AWS Section to be known as the Providence (R.I.) Section. Approval was granted and on June 5th charter members held a dinner meeting. H. Thielsch, who was very active in organizing this section, reports a total of 101 members of whom 84 are new members of the SOCIETY. We all welcome this group which becomes our eighty-second active section.

• June 13th marked a meeting of the Technical Council of the Board of Directors held in Pittsburgh with its chairman, First Vice-President G. O. Hoglund, presiding. It was agreed that E. A. Fenton should be made Technical Secretary and that an assistant to the Technical Secretary should be hired.

• C. E. Jackson, Chairman of the Educational Activities Committee, outlined the extensive activities of this committee and its several subcommittees during the past two years. These activities, conducted with very little assistance from headquarters staff, include the outstanding symposium held at the annual meeting in Philadelphia, and are concerned with the development of outlines and texts for AWS Section courses, in-plant training, apprentice training, college training and visual aids. It was agreed that staff assistance for this important program was essential and should include a secretary for EAC who would coordinate material, prepare final drafts of outlines and texts, and serve as headquarters contact for Section Liaison Representatives. It was further agreed that during the current year Handbook Editor A. L. Phillips would act as secretary for EAC.

• The Technical Council discussed in detail staff problems, in providing adequate headquarters support for technical, handbook and educational committee activities which are being continuously expanded even though Society finances do not permit the addition of staff members. The National Secretary was instructed to assist the Technical Secretary and Handbook Editor in planning their activities so as to provide full secretarial service to main committees only. In general, subcommittees will be expected to keep their own records and furnish copies to the proper staff members.

• Exposition Manager Kenworthy, Assistant Secretary Mooney and your National Secretary journeyed to St. Louis on June 25th and 26th to confer with the Fire Marshal and other city officials, exposition hall and hotel managers, convention and housing bureau staffs, and others in order to complete preliminary arrangements for our 1958 Annual Meeting and Welding Exposition to be held there April 14th to 18th. Harvey M. Gillerman, 1956–57 Chairman of the St. Louis Section, who has been named Chairman of the St. Louis Arrangements Committee, held an orientation meeting for the key men who will assist him in planning local arrangements for this convention.

• On June 27th and 28th your National Secretary joined District Director P. V. Pennybacker in a meeting of District 9 Section Officers held in Shreveport, La. with the local Section, of which Jack York is Chairman, acting as host. Hurricane Audrey tried hard but failed to stop a delegation of five from Houston, headed by Chairman Roy Pringle, who responded to a 4:00 A.M. call and left ahead of the storm in a private plane. Representatives from Dallas, Houston, Oklahoma City, Shreveport and Tulsa Sections and the Austin Division of the Houston Section took part in the conference. Other Division representatives were prevented from attending by the hurricane weather. A carefully planned program resulted in an unusually productive group of discussions.

*Fred L. Plummer*

# EAC DOINGS

## Welding Education— Correspondence Courses

**by William J. Williams**

During World War II the companies which met their production goals from the start were those with established training programs in operation. Education and job-related training, consequently, are now regarded with much the same importance as the installation of new machinery.

Processes, products, machines and industries have become too complex for the necessary knowledge and skill to be "picked up" by observation alone. Know-how alone is insufficient today; it must be supplemented with know-why. This is where education works side by side with industry. Industry supplies two of the necessary factors—the work experience and the opportunity to observe how it is done. The third factor, related study, must be provided by education.

Relatively few of our personnel engaged in welding operations have obtained their specialized knowledge from any single source of formal education. Many have learned by observation, others by inplant training programs, some by courses given by manufacturers

**William J. Williams** is Director of the School of Shop Practice, International Correspondence Schools, Scranton, Pa.

and others by university, college, vocational or correspondence courses.

No one method of disseminating knowledge will fulfill all the needs of industry and all the requirements of an individual. Each method is good and each serves a particular purpose.

The problem is not the method, but the lack of welding educational facilities available for the number who need them. Industry's lack of trained workers poses the real problem. In 1910 unskilled workers accounted for 36% of the work force. In 1950 the percentage of unskilled was down to 19%. Each year the percentage of unskilled workers required by industry falls still lower and it will continue to fall with each technological advance. Lack of skilled workers is actually retarding the progress of industry in some fields.

Correspondence courses have become an integral part of our education system and supply a need which would be difficult to fill by any other means. The merits of one system of education versus another can be argued at length but the fact remains that education can be brought to many people by no other means than by mail.

Trade and vocational schools do not always supply the answer to an individual's need. A student must be brought to the source of the education whereas by correspondence the education is brought to the student. Furthermore, a still more important factor must be taken into consideration: there simply are not enough schools available to house prospective students.

Among the advantages of correspondence courses are the following:

1. The student can continue his work while studying.
2. He can study at his own pace and at hours convenient to him.
3. If his work takes him to another location his "education" accompanies him.
4. Psychological difficulties are eliminated. An older student prefers to study in the seclusion of his home rather than suffer the possible embarrassment of appearing slower mentally than students younger than himself.
5. The effort of hurrying home, changing clothes and rushing off to class several nights a week is eliminated.
6. A student is not restricted by semesters. He may begin at any time and, if he so desires, work through the periods when schools are closed for vacations.

Correspondence study is a valuable tool. It cannot be expected to take the place of a formal education but it can fill the gaps in a formal education. When an education is interrupted by circumstances beyond the control of the student, correspondence study permits him to continue his studies when circumstances become more favorable.


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## EMPLOYMENT OPPORTUNITY FOR ENGINEER

**AWS is seeking an engineer to join Headquarters' Technical Staff as Assistant to the Technical Secretary.**

### Here are the duties—

Working with AWS technical committees in gathering and correlating technical data; preparing minutes, reports and other records of committee activities; editing standards for publication as completed.

Organizing and correlating related activities for most efficient progress.

Disseminating technical information in answer to inquiries from industry.

Related duties as assigned.

### Here are the qualifications—

Ability to work with technical men at all levels in a cooperative manner. This is necessary to successfully deal with committee personnel, AWS members and the general public.

A degree in engineering, any branch.

At least three years experience in engineering work, preferably in welding or allied fields.

### Here is an opportunity—

The man we are seeking has initiative and imagination and is interested in becoming familiar with welding in all its aspects and for every type of application. Salary will be commensurate with qualifications and experience.

If interested in being interviewed for this position, send a resume* of your education, experience and personal background to

**Technical Secretary**
**American Welding Society**
**33 West 39th Street**
**New York 18, N. Y.**

* Will be held confidential.

Correspondence courses must be exceptionally well written and in language suitable to the educational standard of the student. No teacher is present from whom further explanation may be obtained. At the time of reading, the student is on his own. The need for simple, clear-cut statements and short, direct explanations is obvious, if the student is to obtain maximum benefit from the course.

There are few occupations which cannot benefit from correspondence study. It gives a student, whether he be a graduate engineer or a trainee welder, the opportunity to improve his position by job-related study. It enables him to select the subject or subjects he needs without having to adhere to a curriculum in which there may be subjects he does not need. This high degree of selectivity permits a student to pinpoint his study to his present or future activities.

Correspondence education has proved its value. It takes its place with other methods of disseminating knowledge. It is an additional tool with which to keep pace with the ever-increasing demand for trained men. Education and training alone will give us the skilled working force we need to maintain our position as the world's greatest industrial nation.

## *DESIGN PAPERS*

Papers dealing with the progress of welding in the field of *structural design* and *machine design* are solicited for the 1958 AWS National Spring Meeting in St. Louis, Mo. For proper consideration, manuscripts or 500-word abstracts, must reach AWS Headquarters prior to August 15, 1957. Send all manuscripts or abstracts to:

AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

## CHANGE OF RESIDENCE ADDRESS OR COMPANY AFFILIATION

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**Note:** To assure that your copy of the Welding Journal is mailed to your new address, this change of address notice must be received at American Welding Society, 33 West 39th Street, New York 18, N.Y., no later than the 25th of the month previous to issue mailing.

# Section News and Events

as reported to Catherine O'Leary

## GASEOUS FUELS

**Chicago, Ill.**—The regular monthly meeting of the *Chicago* Section was held on May 12th. Speaker was A. F. Chouinard, director of District No. 7. His subject, "Gases Used in the Welding Industry," dealt with the basic physical properties of gaseous fuels used in the welding industry. Color slides were used in presenting the subject which gave facts and figures on flame temperatures, heat contents and combustion ratios.

The pre-meeting movie, which portrayed the building of the Golden Gate Bridge from its infancy, was of interest to the group even though it was an all rivet rather than welding construction.

## ANNUAL PICNIC

**Dayton, Ohio**—Ninety-six members and guests attended the Annual Picnic sponsored by the *Dayton* Section and held at the Inland Activities Center in Dayton.

The picnic began at 5:00 P.M. on Tuesday, June 11th. The program included games, bingo, entertainment, refreshments and dinner. The climax of the evening was the awarding of past-chairman certificates to all of the former chairmen of the Section.

## ANNUAL LADIES NIGHT

**Detroit, Mich.**—*The Detroit* Section's annual "Ladies Night" party was held on May 18th at the Latin Quarter in Detroit. The party was a complete sell-out and was attended by some 850 guests.

Various companies donated door prizes and some extremely fine prizes were displayed on the stage.

Dinner was served at 6:30, followed by distribution of door prizes and a Fur Fashion Show and Floor Show. Dancing started at 10:30 with two bands playing continuously.

National president Chyle and his charming wife were guests of Mr. and Mrs. Crawford and Mr. and Mrs. Wolgast.

This annual party is one of the best and largest in the Detroit area and has become one of the better parties to attend—thanks to a very hard working Section group.

## DETROIT SECTION HOLDS LADIES NIGHT

The annual Ladies Night Party held by the Detroit Section on May 18th was attended by some 850 members and guests. Here's part of the large crowd

Past President John J. Chyle and his charming wife were among the guests. They are shown above with Mr. and Mrs. T. J. Crawford and Mr. and Mrs. R. P. Wolgast

## PLANT TOUR

**Troy, Ohio**—Thirty-three members of the *Indiana* Section participated in a very fine tour of Hobart Bros. Co., Troy, Ohio, on May 24th.

After the tour and prior to dinner in the company cafeteria, E. A. Hobart, president, gave an interesting talk on Hobart's mining operations in Florida. Many of the minerals mined are used in the company's electrode coatings.

A business meeting followed dinner and the following officers were elected for the 1957–58 term: Chairman, Edman F. Holt; First Vice-Chairman, Doug Fitting; Second Vice-Chairman, Robert Hilbert; Treasurer, Fred Watts; and Secretary, Mercedes Spotts.

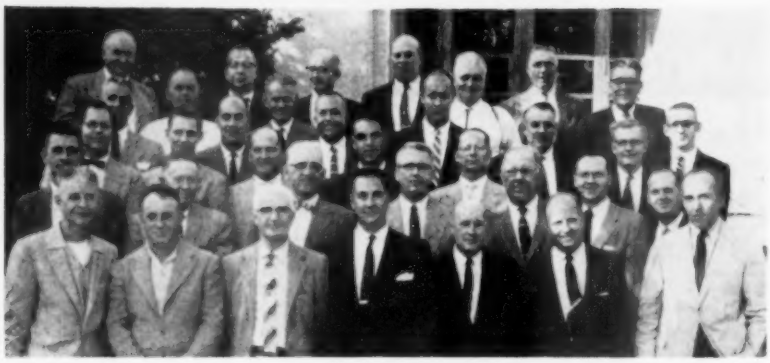
Following the business meeting a talk on power sources for arc welding was given by John Headapohl AWS, of Hobart's special equipment division.

## WELDMENT PERFORMANCE

**Allentown, Pa.**—P. P. Puzak, head, Welding Section, Metallurgy Division of the Naval Research Laboratory, was the technical speaker at the May 6th meeting of the *Lehigh Valley* Section. His subject, "Factors Influencing Service Performance of Weldments," dealt with problems of welding structural steel and methods of evaluating these weldments. Slides were shown on the performance of various weldments and examples of brittle failure in ships and pressure vessels.

Methods for predicting weld failures were accomplished by observing sharp crack defects from arc strike and from series of explosive-type tests. Working behavior of metals could be predicted in specific types of

## INDIANA SECTION TOURS HOBART PLANT



On May 24th, thirty-three of the above members of the *Indiana* Section toured Hobart Bros. plant at Troy, Ohio. At right is W. H. Hobart, Jr., who welcomed the visitors to the plant

loadings from the explosive and drop-weight tests.

The speaker stated from observations that were noted in failures in ships and pressure vessels that "a fracture starting in one place can run through a whole series of plates and is dependent on the plate quality, type of service and temperature." The significance of Charpy V tests to crack-starter tests in ship steel was pronounced. The correlation of the Charpy V test at various test temperatures above pressure-vessel failures was noted. It was observed in some ship-failure instances that welds stopped a continuation of cracks in plates.

From the above tests and observations it was possible to evaluate welds and types of steel for service conditions of use. The service conditions of use were classified as general, accident and military.

The objective was "what an engineer can predict for a certain service use from Charpy V tests to eliminate failures in weldments."

## AIRCRAFT ENGINE STRUCTURES

**Huntington Park, Calif.**—The *Aircraft and Rocketry Panel* of the Los Angeles Section held its last technical meeting of the season on June 6th at the Elks Lodge in Huntington Park with 58 members and guests present.

Speaker of the evening was Frank Harkins AWS, chief process engineer for the Solar Aircraft Co., San Diego. His subject for the evening was "Application of Inert-Arc Welder Processes to High and Low Alloy Aircraft Engine Structures." In his paper, Mr. Harkins covered the many problems encountered by the welding engineer where the specific use of these processes is made mandatory by engineering callout to the exclusion of other welding processes. In discussing the many problems encountered, the speaker described the efforts put forth at Solar in finding acceptable solution to them. The paper was very well presented and well supported with slides showing the many mechanized uses of automatic inert-arc welding. Upon the conclusion of his presentation, Mr. Harkins was presented with a pen set in appreciation of a job well done.

## EXECUTIVE COMMITTEE MEETING

**Los Angeles, Calif.**—The *Los Angeles* Section held its last Executive Committee meeting for the year on June 13, 1957.

The meeting was held in the Trojan Room of the Biltmore Hotel in Los Angeles, with Charles B. Smith, Section Chairman and Asst. Chief Process Engineer for the Douglas Aircraft Co., Long Beach plant, presiding.

Guests present were National President C. P. Sander of Consolidated Western Steel; W. W. Wakee, Chairman-elect for the coming year of Cal. Poly's Student Chapter and student E. P. Bongio of Cal. State Poly.

## HARKINS SPEAKS ON AIRCRAFT WELDING

Seated at the speaker's table, during the June 6th meeting of the Aircraft and Rocketry Panel of the Los Angeles Section are, left to right, Harlan Meredith, John Ross, guest speaker Frank Harkins, Panel Chairman Mario Ochieano, Leo West and Howard Eubanks

Mr. Harkins in the process of delivering his talk on application of inert-arc welding processes to the high and low-alloy aircraft engine structure

Mr. Ross, Section Secretary, addressing the members and guests present on the advantages of membership in AWS

## AT JUNE MEETING OF LOS ANGELES SECTION EXECUTIVE COMMITTEE

Newly elected officers of Los Angeles Section are shown with AWS President C. P. Sander at the June 13th meeting of the Executive Committee. Left to right, are Dick Hayes, secretary; Mr. Sander; D. P. O'Connor, chairman; and John Ross, vice-chairman

Outgoing chairman of Aircraft and Rocketry Panel, Mario Ochieano, is pictured above with incoming chairman, Leo West

Chairman Smith opened the meeting by introducing C. P. "Sandy" Sander, who announced the resignation of J. G. Magrath as national secretary and the appointment of F. L. Plummer as his successor.

Chairman Smith then called upon each committee chairman individually to make a report of his activities for the past year and a discussion was held and, where needed, suggestions for improvement were given.

Mr. Wakee, a student at Cal. State Poly, discussed the problem of summer employment for students and distributed copies of a program to the members explaining how the Student Chapter can cooperate with industry.

Mr. Drahos reported that the U. S. Dept. of Commerce was compiling a complete report of all welding material that will soon be available.

## ANNUAL SOCIAL HELD BY MADISON SECTION

Part of the attending members and their ladies at dinner during the annual Social held by the Madison Section

Fred Theiler, outgoing Section Chairman, presenting Meritorious Certificate Award to past chairman, Howard Adkins

Ray Knudtson, newly installed Section Chairman, presenting a token of appreciation to Mr. Theiler

## ANNUAL SOCIAL

**Madison, Wis.**—The annual social of the *Madison* Section was held at the Blackhawk Country Club in Madison. A dinner and dance followed a cocktail hour which began at 5:30. The function was attended by forty members and guests and brought to an end a successful year.

The evening was highlighted by the presentation of the Meritorious Certificate Award to Howard E. Adkins who was chairman during 1955–56.

In addition to the past chairman's pin, Fred Theiler was presented a token of appreciation on behalf of the Section.

The following officers were installed for the coming year: Chairman: Ray Knudtson; Vice-Chairman: Harold May; Second Vice-Chairman: Carl Seitz; Secretary-Treasurer: Kenneth Smith.

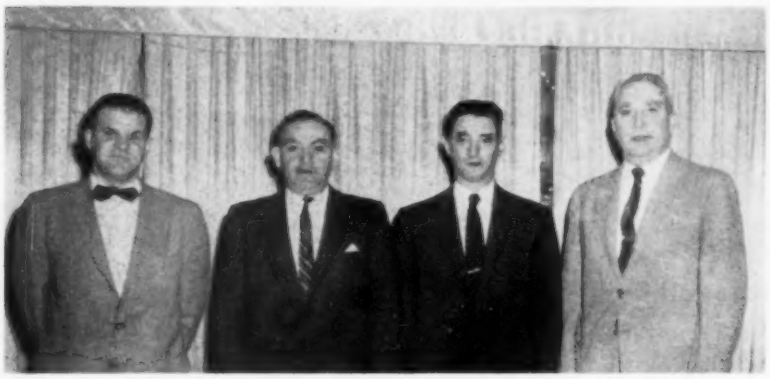
## GET-TOGETHER MEETING

**Newark, N. J.**—The regular monthly meeting of the *New Jersey* Section was held on Tuesday evening, May 21st at the Essex House Hotel in Newark.

Following the usual custom, the last meeting of the season was a non-technical get-together featuring Samuel H. Ramsay, one of the country's foremost humorists, who gave his audience an evening of rare entertainment with his subject "The Value of a Sense of Humor."

The evening's activities started with a Social Hour at 6:00 P.M. with cocktails and appetizers, followed by Dinner and short film in color entitled, "Challenge on the Lake" showing Don Campbell breaking the Worlds speed boat record with his jet propelled boat "The Bluebird."

## NEW JERSEY SECTION ELECTS NEW OFFICERS



The new officers elected by the New Jersey Section for the 1957–58 fiscal year are shown at the May 21st meeting. Left to right, are W. G. Benz, vice-chairman; E. Di Liberti, chairman; H. L. Hoffman, treasurer; R. V. Thornton, secretary

Chairman Di Liberti presents past chairman's pin to outgoing chairman John Hila

Chairman John Hila introduced the newly elected officers for 1957–58 as follows: Chairman, E. Di Liberti; Treasurer, H. L. Hoffman; Vice-Chairman, W. G. Benz; Secretary, R. V. Thornton; Executive Committee—1958: E. Bowden, F. Simms, R. P. Hubbard, and W. R. Apblett.

### ANNUAL DINNER DANCE

**Olean, N. Y.**—The June meeting of the *Olean and Bradford* Section was held on June 20th at the Castle Restaurant, Olean, N. Y. This was the annual dinner and dance for the members and their ladies. A wonderful evening was enjoyed by forty members and ladies.

Election of officers for the fiscal year was held as follows: Chairman, Ralph Barnes, Clark Bros., Olean, N. Y.; Vice-Chairman, Jack Keyte, Dresser Mfg., Bradford, Pa.; Secretary, William Daley, Clark Bros., Olean, N. Y.; Treasurer, Sid L. Worth, Cattaragus Co., Little Valley, N. Y.; Directors, Felix Schneble, Andrew Casper, Harold Collins and Michael Robinson.

### ANNUAL DINNER DANCE

**Philadelphia, Pa.**—The annual dinner dance of the *Philadelphia* Section was held on Saturday, May 25th at the Germantown Cricket Club, with 250 members and guests present.

Highlights included the traditional presentation of a gavel and pin to the retiring chairman, A. M. Garcia, by Byron Gates, chairman. A new ceremony was inaugurated in which a gavel was presented to Mr. Gates by Mr. Garcia.

Each lady received an attractive pearl choker, and drawings were held for the distribution of the many door prizes.

### ORGANIZATION MEETING

**Providence, R. I.**—On June 5, 1957 a charter was issued for the organization of a Section to be known as the "Providence" Section. On this date a dinner meeting was held at Johnson's Hummocks, with 62 new charter members attending the dinner and 71 the subsequent meeting.

The roster at this meeting shows a total of 101 members, of which 17 are transfers from the Boston Section and the remaining 84: new members.

After the dinner, a discussion was held by Sidney Low, director of District 1, on the organization and functions of the SOCIETY.

Helmut Thielsch, of Grinnell Co., then discussed the "where, when and what" type of meetings to be held monthly. Questionnaires were distributed to each member for choosing subjects in order of priority of interest. An Educational Lecture Series for the fall was also discussed.

### PLASTICS

**Seattle, Wash.**—The March meeting of the *Puget Sound* Section was held on March 14th at the Engineers Club in Seattle. The subject of the meeting was "Fabrication of Rigid Polyvinyl Chloride Plastics." This meeting was a departure from the normal welding subjects usually discussed at Section meetings. The Program Committee believed that there had been sufficient comment in the area on the use of PVC piping and fabrication to warrant a speaker on the subject.

James Sheehy, the West Coast manager for the Tube Turns Plastics Company, gave an informative history and present product use of PVC pipe and sheet in the industrial construction industry.

W. H. Rice [AWS], consultant for the Electric Steel Foundry Co. was the second speaker. Mr. Rice has spent considerable time in the field application of PVC.

## PHILADELPHIA SECTION HOLDS ANNUAL DINNER-DANCE

Among those seated at the head table during the annual dinner of the Philadelphia Section were, left to right: Dinner Chairman R. W. Thomas, Mrs. Thomas, Incoming Chairman B. D. Gates, Mrs. Gates, Outgoing Chairman A. M. Garcia and Mrs. Garcia

An opportunity to join plastics with heat and chemical was given all those present.

## LADIES NIGHT

**San Antonio, Tex.**—"Ladies Night" for the *San Antonio* Section was held on the regular meeting night, May 28th, at the Lone Star Brewery. Don Berry of the Brewery welcomed 65 members and 300 guests who enjoyed a delicious Mexican dinner served by the Patio Food Co.

A very interesting film, entitled, "An African Safari," was shown and narrated by Louis Strumberg of Patio Foods. This was an actual hunting expedition into a section of West Portugese Africa never before entered by white men where several world record kills were made, including the largest elephant.

The highlight of the evening was the presentation of a trophy to Edmund Guemes, a student at the San Antonio Vocational and Technical School, who was selected as the most versatile welding student of Southwest Texas.

An evening of dancing was enjoyed after the regular program.

## EDUCATIONAL LECTURES

**San Jose, Calif.**—The regular meeting night of the *Santa Clara Valley* Section for April was waived in favor of a series of three educational lectures on the subject of Metallurgy. The meetings were held in the San Jose State College Engineering Auditorium on the evenings of April 23, 24 and 25.

Dr. Robert A. Huggins AWS, Assistant Professor of Metallurgy at Stanford University, was the speaker and his subjects were as follows: "Principles of Welding Metallurgy," "Special Metallurgical Problems in Welding," and "Welding Metallurgy of Special Materials."

The lectures were well attended and it is the intention of the Section to carry on these educational lectures every year.

## NONDESTRUCTIVE TESTING

**San Jose, Calif.**—One hundred and ten members and guests of the *Santa Clara Valley* Section attended the monthly meeting held on May 21st at the Red Barn.

The speaker was C. E. Betz AWS, vice-chairman of the board of directors of the Magnaflux Corp., Chicago, Ill. His subject was "Nondestructive Testing in the Inspection of Welds." Mr. Betz presented a general survey and discussion of various nondestructive test methods in use in the inspection of welds. Some of the latest developments in the use of magnetic particle and of penetration inspection in the field of welding were described in detail with slides showing some recent installations. This meeting was a huge success.

## TOLEDO MEETINGS

**Toledo, Ohio**—*The Toledo* Section announced the formulation of its program schedule for the 1957–58 meeting year as follows:

| | |
|---|---|
| September 17 | Aluminum and Magnesium Welding |
| October 15 | Plant tour through new SOHIO Refinery |
| November 19 | Resistance Welding |
| December 17 | "Stump the Experts" Program |
| January 21 | Hard Facing |
| February 18 | Low Chrome Alloy Welding |
| March 18 | Alloy Cutting Clinic |
| April 15 | Welding for Code Work |
| May | Annual Dinner-Dance |

It is quite obvious that these subjects will cover the main interests of the industries of Toledo and the surrounding area, and will aid in keeping area personnel abreast with this rapidly expanding welding industry. The speakers for these meetings will be men who are well known and respected for the work they have done in their particular field towards better welding techniques and quality. Only by getting this information firsthand and accurately can industry hope to produce the equipment and pipe lines that are so critical in our planned atomic reactors.

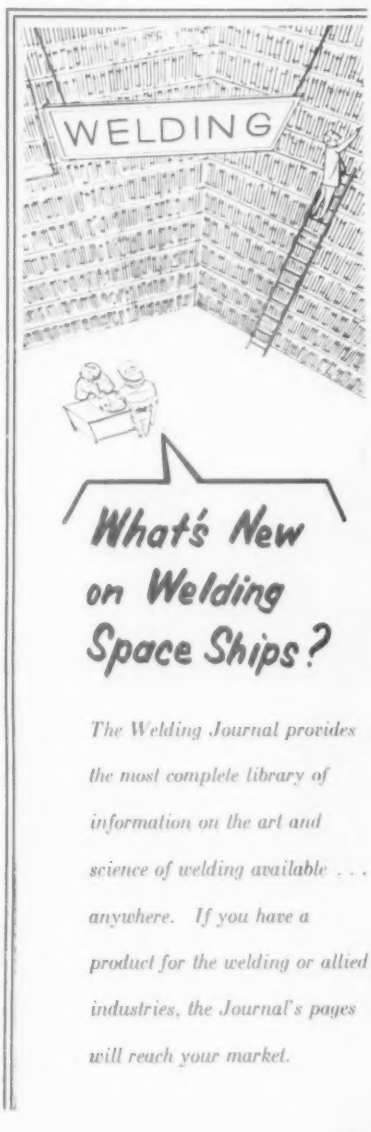
The Toledo Section meets at the Maumee River Yacht Club with dinner at 6:30 P.M. sharp and meetings at 8:00 P.M. The Section extends an invitation to everyone interested in these subjects to attend these meetings.

## WELDING IN MIAMI

**Miami, Fla.**—A preliminary meeting among building officials of the City of Miami, Dade County, representatives from industry and Paul R. Greenfogel AWS, chairman of the *South Florida* Section, in February, 1957, established the groundwork for a qualification system for welding inspectors and operators. The AMERICAN WELDING SOCIETY was asked to prepare examinations by which the building committee would determine whether a prospective inspector or operator could qualify for a welding license in the Miami area. The license itself consists of a card which lists to what extent the individual is qualified and also bearing his thumb print and photograph.

By the issuance of a qualification card, the individual once qualified by an approved testing organization, is automatically accepted for any job in the area requiring qualified welding.

According to Mr. Greenfogel, the program is looked upon with approval by engineers and architects, who can now specify welding and realize that qualified personnel is available to do the work satisfactorily.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# New Members

*Effective June 1, 1957*

*MEMBERSHIP CLASSIFICATION*

A—Sustaining Member B—Member C—Associate Member
D—Student Member E—Honorary Member F—Life Member

*Total National Membership*

| | |
|---|---|
| *Sustaining Members* | *168* |
| *Members* | *6,058* |
| *Associate Members* | *6,419* |
| *Student Members* | *165* |
| *Honorary Members* | *10* |
| *Life Members* | *14* |
| *Total* | **12,834** |

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Null, Lawrence E. (C)

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Horn, Robert L. (B)
McClelland, George D. (B)
Mills, W. W. (B)
Solberg, C. M. (C)

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Herrington, A. O. (C)

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Sorrentino, Peter A. (B)
Stevenson, C. Allan (B)
Sullivan, Joseph P. (C)
Wright, Norman W. (C)

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Kadish, Victor (B)
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Oelschlager, Donald D. (B)
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Payne, William M. (B)

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Creighton, Roger Ness (D)
Dumbauld, Mark E. (D)
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Lott, Jack E. (C)
Miller, Richard W. (C)
Niemann, John T. (C)
Payne, Davis M. (C)
Schnabel, Robert L. (D)

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Jones, Harry C. (C)

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Strand, Murray A. (B)
Tann, Eugene (B)
Young, W. H. (B)

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Maughlin, Richard K. (D)

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Taylor, Roy M. (C)
Welling, Eugene A. (B)

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Dougan, George L. (B)

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Benitez, Roberto C. (B)
De La Torre, Manuel O. (B)
Palomar, Pablo J. (B)

## *Members Reclassified*

**During the month of June**

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**FOX VALLEY**

Abel, C. Burnell (B to A)

**HOUSTON**

Cashman, Michael R., Jr. (C to B)

**KANSAS CITY**

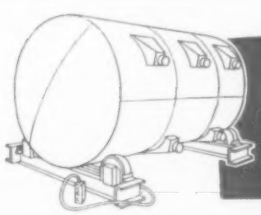
Hoyt, Robert L. (C to B)

**LOS ANGELES**

Ochieano, Mario L. (C to B)
Smith, Charles Brent (C to B)
Young, George R. (C to B)

**WESTERN MASSACHUSETTS**

Einfurer, Donald C. (C to B)

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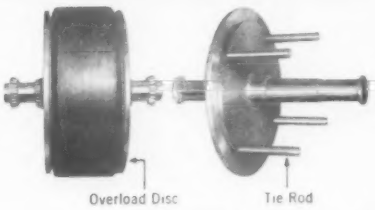


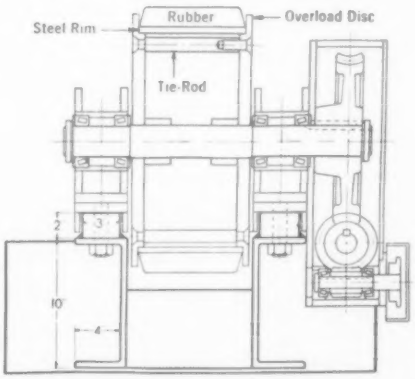


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# Current Welding Literature

For copies of articles, write directly to publications in which they appear

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# ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D. C.

2,780,717—Method of Welding—Howard E. Bernhardt, Milwaukee, and Kenneth W. Davey, Wauwatosa, Wis., assignors to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

A method of fabricating a welded article from two metal parts having complementary edges to be welded is disclosed by this patent. First the parts to be welded are positioned in metal castings formed therearound to leave the edges of the metal parts to be welded protruding from the remainder of the castings. The castings are then so positioned as to bring the exposed edges of the metal parts to be welded into engagement with each other and a weld action is effected thereon. Thereafter the material cast around the metal parts initially is heated to melt it from the welded article.

2,780,718—Spot Welding Tip—Henry A. Mullen, Wauwatosa, assignor to Ampco Metal, Inc., Milwaukee, Wis., a corporation of Wisconsin.

Mullen's patented tip comprises a shank having a center bore with an enlarged outer end, and a replaceable head is received in water sealing and guiding wedging engagement within the outer end of the bore of the shank. Other means are provided to aid in maintaining the alignment of the head and shank under welding pressures exerted thereon.

2,780,719—Electrode Holders for Hand-Welding—Bernard T. Ballington, Sheffield, England, assignor to English Steel Corp. Ltd., Sheffield, England.

This electrode holder includes an elongated metal carrier and a heat-insulated hand grip. A conducting gripper is provided on the carrier at one end thereof, and the carrier has fins provided thereon for the dissipation of heat tending to flow by conduction through the carrier between the ends thereof.

2,781,026—Control Apparatus for Flash Welding Machines—Hans Alfred Schlatter and Emil Wegmann, Zollikon-Zurich, Switzerland, assignors to Firma H. A. Schlatter A.G., Zollikon-Zurich, Switzerland.

Special control cylinders and pistons are disclosed in and covered by this patent which relates in general to a flash welding machine. The patent covers the details of the piston and cylinder connections and control action performed thereby.

2,781,441—Traveling Apparatus for Welding Horizontal Joints Between Vertically Disposed Plates—William I. Ballentine, Jr., Whittier, and Harry C. Brest, Pomona, Calif., assignors to United States Steel Corp., a corporation of New Jersey.

This apparatus is adapted to hold flux in contact with a longitudinal seam formed between vertically disposed plate edges. A carriage is provided and is slidable in a frame in the apparatus for movement toward and from the plate edges being welded. A shelf means is mounted on a portion of the apparatus and adapted to engage the side of one of the plates being welded so as to aid in positioning flux in a desired manner for association with a horizontal weld seam being produced.

2,782,293—Device for Preventing Tube Collapse in Tube Mills—Veryl H. Sanner, Toledo, Ohio, assignor to the Etna Machine Co., Toledo, Ohio, a corporation of Ohio.

This patent relates to a tube mill for progressively forming a thin-walled metal ribbon into tubular form and resistance welding the edges thereof together as the form is advanced past a pair of electrodes. Pressure rolls squeeze together the edges of the tube form at the point of weld. The novel feature of the patent is that it provides a plug supported within the tube and restrained against axial movement in the region underlying adjacent portions of the electrodes and the pressure rolls. The plug has surfaces to guide and support the adjacent edge portions of the tube as the same pass to the pressure rolls where they are brought into engagement.

2,782,488—Strip Splicer—Lysle V. Anderson, Warren, Ohio, assignor to E. W. Bliss Co., Canton, Ohio, a corporation of Delaware.

This patent is on a specialized apparatus for splicing metal strip ends together. The apparatus includes means for shearing the ends of the strips and for welding them in desired relationship.

2,782,491—Method of Making an Electrical Connection—Ward Cole, Anderson, Ind., assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

In this patent, Cole has developed a method of making a specialized electrical connection wherein a terminal is provided with a groove with sharp edges on a portion thereof. A bare portion of the conductor is placed in the groove and sharp edge portions of the terminal are caused to melt and flow under pressure and heat to fuse with the bared portion of the conductor.

2,782,495—Joining of Metals—George W. Beck, Dayton, Ohio, and Howard F. Rentz, Detroit, Mich., said Beck assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware and said Rentz assignor to Briggs Manufacturing Co., Detroit, Mich., a corporation of Michigan.

The present patent relates to a method of joining two sheet metal parts having inturned flanges along the joining surfaces. A joining strip of substantially T-shape in cross section is provided and is placed with the leg portion of the joining strip extending between the flanges on the sheet metal parts. Uncured, tacky rubberlike beads are positioned between portions of the joining strip and the adjacent metal parts. Next the flanges of the metal parts and the leg of the joining strip are welded together and the beads are deformed under the pressures exerted thereon. Thereafter the rubberlike material is cured to cause the beads to bond to the adjacent metal surfaces to form a weatherproof seal between such associated metal surfaces.

2,782,497—Method of Making Clad Steel—John M. Campbell, Washington, Pa., assignor to Composite Steels, Inc., Washington, Pa., a corporation of Pennsylvania.

Campbell's patent relates to a continuous method of making a layer of carbon steel strip and stainless steel strip. The stainless steel strip is plated with a pressure weldable material and the continuous strips are brought together and welded at their edges to form a composite strip. Then the composite strip is heated to a pressure welding temperature and the composite strip is rolled under sufficient pressure to weld the component strips together throughout their widths.

2,782,498—Method for Making Composite Stock—Peter Mushovic and Harold W. Schultz, Dayton, Ohio, assignors to General Motors Corp., Detroit, Mich., a corporation of Delaware.

A method of bonding aluminum to steel is disclosed by this patent. In this instance, cleaned and roughened bonding surfaces are provided on the aluminum and steel and they are rolled under pressures such as to deform the aluminum by 65 to 80% of its original thickness while subjecting them to uniform temperatures between 800 and 1010° F so that a strong and ductile bond is formed between the adjacent surfaces of the aluminum and steel layers.

2,783,359—Process for Arc Welding of Circular Seams on Pipes in Substantially Horizontal Position—Hans Gunther, Mosbach (Baden), Ger-

many, assignor to Kraftanlagen A. G., Heidelberg, Germany.

In this patent, the rims of two stationary pipe sections are positioned to form a substantially annular gap extending in a vertical plane. The method includes the step of elastically deforming the rims to form a gap which is wider at the sides than at the bottom and top, and causing a welding arc to progress along the unequal width gap while the pipe sections remain stationary.

2,783,360—Welding Torch—Max R. Osborn, New York, N. Y.

This new welding torch has a special member therein for circulating cooling medium through the welding torch, while it also has a collet in a conducting member portion of the torch for engaging the electrode. Other means actuate the collet to clamp or release an electrode positioned therein.

2,783,361—Welding Process and Apparatus—Robert E. Semple, Temple City, Calif., assignor to Beckman Instruments, Inc., Fullerton, Calif., a corporation of California.

The present patent relates to a method of welding two small metal filaments. In the new method, one filament is moved towards the other until they are in contact and then the filaments are separated a slight distance to form a gap between the previously engaged portions of the filaments. Next a capacitor charged at a potential greater than the breakdown potential of the gap is discharged through the gap to establish a spark of sufficient intensity to weld the filaments together.

2,783,362—Multiple Electrode Arc Welding Assembly—John Hassler, Cleveland, Ohio, assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

This new electrode is a dual welding electrode assembly. It is made from a pair of separate, distinct welding electrodes, each having a separate insulating flux coating over a central core. One end of each electrode has the coating skinned from the core thereof and electrode spreading means are positioned at the skinned ends of the electrodes to hold them at a slight angle to each other. The electrodes converge and are held in tension against each other with their insulating coating touching and in line contact over a major portion of their length.

2,784,014—Flux-Filled Arc Welding Stud—Frank K. Kelemen, Haddonfield, N. J., assignor to KSM Products, Inc., Merchantville, N. J., a corporation of New Jersey.

This new welding stud has a recess in the weld end thereof and a solid mass of ductile fluxing metal is received in such recess and extends therefrom. The protruding portion of the flux mass includes a base portion adjacent the weld end surface and substantially greater in diameter than the diameter of the recess formed in the stud end. The protruding portion of the flux metal constitutes more than one-half of the total of such flux metal.

2,784,285—Brazing Apparatus—William F. Brauer and Theodore W. Kalbow, Chicago, Ill., assignors to Western Electric Co., Incorporated, New York, N. Y., a corporation of New York.

This patented brazing apparatus includes an annular split induction coil having a bore through the center portion thereof and means for resiliently holding a sheet in alignment with the bore. Other means support a second shell into which the first shell is nested and Lavite rods extend through the bore of the induction coil for limiting movement of the shells into the coil.

2,784,293—Electrode Holder—Albert H. Adams, Maple Heights, Ohio.

In Adams electrode holder, a special electrode engaging member is provided. Such engaging member connects to the remainder of the holder in an adjustable manner and is adapted to control the flow or discharge of gas from the electrode holder, dependent upon the position of the electrode engaging member.

2,784,294—Welding Torch—William H. Gravert, Port Washington, N. Y.

Gravert's new welding torch has means for adjustably clamping a welding rod therein. Releasable tension spring means, positioned coaxial with the welding rod, are provided for controlling the clamping action on the weld rod.

2,784,295—Semiconductor Translating Device Conductor Welder and Cutoff Apparatus—Fred Wohlman, Inglewood, Calif., assignor to Hughes Aircraft Co., Culver City, Calif., a corporation of Delaware.

This patent relates to a material welding and cutoff apparatus for manufacturing subassembly components of semiconductor translating devices. The apparatus includes means for bringing a ribbon into contact with a lead, for welding the ribbon to the lead, and for cutting the ribbon at desired portions thereof.

2,784,297—Method of and Apparatus for Forming and Welding Pins to One or Both Sides of a Metal Strip—Albert F. Pityo, Cedar Grove, N. J.

In this patent, an elongated metal strip is positioned for a longitudinal indexing movement, and wires are positioned with their ends in contact with opposite faces of the metal strip. The wire ends are welded to the metal strip and severing devices are provided on opposite sides of the strip for severing the wires to provide pins secured to the metal strip. The severing device is moved longitudinally of the metal strip to move and index it in a longitudinal direction. The cycle can be repeated for securing additional pairs of pins to the metal strip.

2,784,299—Method and Apparatus for Welding Sheet Metal—Karl W. Matthes, Scott Township, Allegheny County, Pa., assignor to Precision Welder & Machine Co., Cincinnati, Ohio, a corporation of Ohio.

Matthes' machine is for welding sheets of metal at adjacent edges and wherein the edges have been flanged and are positioned with the flanges abutted against each other. A pair of squeeze rolls are provided to engage the flanges and squeeze them together, and a roller electrode is disposed to engage the metal sheets at a portion thereof over the squeeze rolls and at points adjacent the outside corners of the flanges. Other means move an electrode into and out of engagement with the sheets for welding action thereon.

2,784,300—Method of Fabricating an Electrical Connection—Paul Zuk, Allentown, Pa., assignor to Bell Telephone Laboratories, New York, N. Y., a corporation of New York.

Zuk's patent is on a method of connecting a lead to a germanium body that comprises forming a platinum wire into a V-shape and mounting the wire apex in contact with a center portion of a button made from germanium containing a large proportion of lead. Current is passed through the button adjacent the apex of the platinum wire to melt a limited portion of the button and the apex of the wire is pushed into the melted portion of the button. Thereafter the current flowing through the button is reduced while maintaining the wire in contact with the button to freeze the platinum wire in the melted button portion.

2,784,301—Method of Arc Welding—George G. Landis and John E. Carroll, South Euclid, Ohio, assignors to the Lincoln Electric Co., Cleveland, Ohio, a corporation of Ohio.

This patent on electric arc welding is for welding the edges of metallic work pieces which may, at points along their lengths, be in slightly spaced relationship. The method uses an electrode consisting of parallel, spaced core wires having surrounding insulating coatings holding the wires in spaced relationship. The electrode is positioned so that one end thereof touches the work piece at the desired point of beginning of the weld, and the core wires are energized from the same electric power source. An electric arc is initiated and allowed to continue to burn back the arc end of the electrode without intentionally moving the electrode either transversely or longitudinally of the desired weld seam during the welding operation.

2,784,349—Electric Arc Welding—Nelson E. Anderson, Berkeley Heights, N. J., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

In this arc welding apparatus, a low frequency source of welding current is connected to an electrode and a workpiece, and an auxiliary high-frequency, high-voltage source of current is connected to supply an arc stabilizing current between the electrode and the workpiece. Variable impedance means are interposed between the low frequency source of welding current and the arc gap to present a high impedance to the high-frequency, high-voltage source when the value of welding current is low, but it presents a low impedance to the low frequency source of welding current. The ratio of the impedance to the high-frequency, high-voltage source to the impedance to the welding current source is greater than the ratio of the frequency of the high voltage source to the frequency of the welding current source.

2,784,410—Welding Helmet and Lens Control—Paul Gentz, Harper Woods, Mich.

Gentz' patented welding helmet includes a lens movable to and from an eye shielding position and controllable by chin actuated means by the wearer of the helmet.

2,784,487—Method of Building Weld Layers by Fusing a Plurality of Weld Rods—Bela Ronay, Glen Burnie, Md.

This patent is for fusing areas in a junction space between adjacent edges of aligned heavy metal sections. The method comprises placing a layer of a plurality of elongated fusion metal rods in the space and applying a sub-melt pre-heat to the rods and to the metal sections in a single pass from end-to-end thereof. Simultaneously a melt-heat is applied at a point behind the pre-heat so that the rods and space walls are first brought to a sub-melt heat and then fused in close succession. This layer is permitted to solidify and then the rod placing, pre-heating and melt steps are repeated until the desired space is filled with a fused weld deposit layer.

2,785,094—Coated Copper Alloy Arc Welding Electrode—Francis Emery Garriott, West Allis, Wis., assignor to Ampco Metal, Inc., Milwaukee, Wis., a corporation of Wisconsin.

The patented arc welding electrode comprises a core wire made from either aluminum-bronze alloys or beryllium-copper alloys. The core wire has a covering thereon made from a mixture of fluorides of the group consisting of alkaline earth metal fluorides and sodium fluoride and including a substantial proportion of barium fluoride. A potassium compound and a silicate binder complete the covering composition.

2,785,279—Apparatus for Electrically Eroding Materials—Everard M. Williams, Pittsburgh, Pa., assignor, by mesne assignments, to Firth Sterling Inc., Pittsburgh, Pa., a corporation of Pennsylvania.

In this electrically eroding apparatus, a condenser is provided and connected to a suitable charging circuit and to a discharge circuit including a workpiece and an electrode. A low-inductive conductor is connected in series in the discharge circuit and its inductance in the presence of current is such that the peak discharge current is greatly increased and its duration is greatly reduced.

2,785,282—Control Mechanism for Welding Apparatus—Ronald F. Brennen and James A. Bucci, Brooklyn, N. Y. assignors to Welding Industry Research & Patent Corp., New York, N. Y., a corporation of New York.

This patent on a control mechanism for a welding assembly relates to apparatus wherein a fixed and a movable electrode are provided. A transformer is provided and has its secondary connected to the electrodes. The invention relates to the provision of a control cylinder and piston for moving the movable electrode and to switch means for closing the welding circuit when the electrodes press on the workpiece.

2,785,283—Welding Circuit—Eric E. Sumner, New York, N. Y., assignor to Bell Telephone Laboratories, Inc., New York, N. Y., a corporation of New York.

Sumner's patent relates to a welding system including a network of a plurality of resistors and a plurality of capacitors in which the effective time constant of the network is a function of two or more products of resistance and capacitance. These products of resistance and capacitance are unequal. Means are provided for charging the capacitors and a welding load is provided comprising two electrodes. The welding load also includes concurrently effective discharge paths for the capacitors through the resistors and the two electrodes.

2,785,284—Electric Discharge Apparatus—Hubert W. Van Ness, East Aurora, N. Y., and Edward C. Hartwig, Walnut Creek, Calif., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patented welding apparatus includes means for applying forge pressure to work and the forge pressure applying means include a first timing circuit for determining, when it times out, the instant when the forge pressure is applied. The apparatus also includes means for supplying welding current to the welder for welding the work, and a sequence timer for timing the operational steps of the welder and including a second timing circuit connected to the supply means for initiating and maintaining the supply of current to the welder. Other means are provided to impress a signal to initiate the timing of the second circuit. The apparatus is characterized by being connected so that connections are provided between the signal impressing means and the first timing circuit for impressing the signal so that it also initiates the timing of the first timing circuit.

2,785,285—Composite Welding Electrode—Arthur A. Bernard, Chicago, Ill., assignor to National Cylinder Gas Co., Chicago, Ill., a corporation of Delaware.

The patented welding electrode includes a circumferentially closed elongated metal sheath having an elongated cavity therein and a granular process material disposed within and filling the cavity. This granular process material is partially embedded in the sheath and some of the granules have specified dimensional limitations.

2,785,337—Arc Welding Apparatus—Arthur E. Johnson, Milwaukee, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

Johnson's patented combination includes a first and second arc welding electrode and a first and a second workpiece. A transformer is provided that has a core and a primary winding movably mounted thereon. Means are provided connected to the secondary of the transformer for providing a direct current flow to one electrode, and an alternating current flow to the second electrode. Another member is provided to move the primary winding relative to the core and thereby regulate both the direct current and alternating current outputs of the welding apparatus.

2,785,459—Method of Making Fusion Weld Sealed Pressure Joint—Otis R. Carpenter, Barberton, Ohio, assignor to The Babcock & Wilcox Co., Rockleigh, N. J., a corporation of New Jersey.

Carpenter's patent relates to a method of forming a special pressure tight tube and tube seat connection between a tube and the wall of a pressure part. The method includes depositing weld metal in a groove around a hole through the pressure part, and positioning the tube in the pressure part and extending through the weld metal. Thereafter the outerperipheral surface of the tube end is fusion seal welded to the previous weld metal deposit.

2,786,127—Work Support for Welders—Paul L. Osweiler, Dayton, Ohio, assignor to Price Brothers Co., Montgomery County, Ohio, a corporation of Michigan.

The patented work support is for use in welding metal mesh. The support includes inflatible means for use in tightly pressing wires together to form parts that can be readily welded into a unit.

2,786,128—Apparatus for Spark Machining—Anthony Hillesden Lines, Pinner, England, assignor to D. Napier & Son Ltd., London, England, a British company.

This patent relates to a sparking machine apparatus in which the tool electrode is of special composition. The composition comprises a matrix of copper and graphite and includes approximately 85% copper and 16% graphite.

2,786,160—Arc Welding Apparatus—Harry J. Bichsel, East Aurora, N. Y., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This arc welding apparatus includes a polyphase transformer having a primary phase winding and a corresponding secondary phase winding for each of its phases, and a variable transformer is included in the apparatus and has a turn ratio capable of continuous variation associated with each phase of the input power source. Each of the variable transformers has an adjustable slider and a reversing switch means associated therewith. Means are provided to mechanically couple the adjustable sliders together and other means mechanically couple the reversing switches for control of the variable transformers.

2,786,204—Adjustable Suspension for Helmets—Jack N. Simpson, Reading, Pa., assignor, by mesne assignments, to Ray-O-Vac Co., Madison, Wis., a corporation of Wisconsin.

This patent relates to a face protecting shield which is pivotally mounted upon a brow band and other strap means which engage the wearer's head. The face protecting shield has an adjustable friction engagement with its positioning means.

# NEWS of The Industry

## G. E. Welding Department to Terminate Business Gradually

Plans for the gradual and orderly termination of the manufacture of arc welding equipment and electrodes by the General Electric Co.'s Welding Department in York, Pa., were announced on July 1st by Harold E. Strang, vice-president and general manager of the Measurements and Industrial Products Division.

Mr. Strang emphasized that General Electric would continue to provide normal renewal parts and in-warranty service on all welding equipment now in the field or to be produced before termination of the business.

"We recognize the responsibility of the Welding Department to its distributors and to users of its products," D. A. Hopper, general manager of the department said. "We will fulfill commitments to users and complete our contractual obligations to distributors."

Mr. Strang said that an organization component will be formed immediately to plan the department's gradual dissolution, with the primary objective of minimizing inconvenience to employees, customers, and vendors.

No plans for the disposition of the Welding Department's plant and facilities in York have been made, Mr. Strang added.

The termination does not affect the manufacture of resistance welding control by GE's Specialty Control Department in Waynesboro, Va.

## World Metallurgical Congress

Chicago will host the 2nd World Metallurgical Congress to be held November 2–8 in conjunction with the 39th annual National Metal Exposition and Congress. Estimates to date include registrations of 575 people from 36 nations. Among the scheduled technical panels at the annual meeting will be sessions on the following subjects: steelmaking and refining; nonferrous refining and fabrication; metal fabrication; heat treatment; inspection and testing; education and research; and metallurgical research. In addition, three panel sessions will be held on "welding and joining." The areas covered will be "ship welding," "electrodes," and "stress relieving and preheating." An active committee, headed by Fred L. Plummer, lists Howard Biers, Union Carbide Corp., Leon Bibber, U. S. Steel Corp., Harry Schwartzbart, Armour Research Foundation, and William Spraragen, Welding Research Council.

## Landis Nominated by ASME

A San Francisco engineering executive, James N. Landis, has been nominated to the office of president of The American Society of Mechanical Engineers. He will be installed in office, after a letter ballot of the membership, during the ASME annual meeting to be held in New York in December, to serve for a term of one year.

Mr. Landis is vice-president of Bechtel Corp., one of the nation's leading engineering firms, and a past chairman of both the San Francisco Section of ASME and of its Metropolitan Section in New York in addition to having held many other responsible Society offices through the last twenty years.

Announcement of his selection came at the semi-annual banquet of the 50,000-member Society during its meeting at the Sheraton-Palace Hotel in San Francisco during the week of June 12th.

## Schier Appointed ASME Secretary

Oscar B. Schier II has been designated Secretary-Elect of The American Society of Mechanical Engineers by unanimous vote of the Society's Council, it was announced recently by Dr. William F. Ryan, ASME President. He will succeed Clarence E. Davies who will retire as Secretary after 23 years of serv-

## WELDING BOOTH AT UNION-INDUSTRIES SHOW

The booth at the Union-Industries Joint Show in Kansas City on May 16–21 was manned by the apprentice training subcommittee of the Education Activities Committee. Ralph Minga [AWS], explains the advantages of welding pipe to Norman Piron, Richard Walsh, John Gorman and George Youngblood

# COMING EVENTS

*A Calendar of Welding Activity*

AWS National Meetings

1958 Spring Meeting and Welding Show:
April 14–18, Statler Hotel, St. Louis, Mo.

NWSA

Central Zone Meeting:
September 12–13, 1957, Sheraton-Gibson Hotel, Cincinnati, Ohio.

Eastern Zone Meeting:
September 16–17, 1957, Commodore Hotel, New York, N. Y.

ASM

November 4–8, 1957. Thirty-ninth National Metal Exposition & Congress, concurrently with Second World Metallurgical Congress, International Amphitheatre, Chicago, Ill.

ice in this office. The post of Secretary is the chief administrative office of the 50,000-member Society.

Mr. Schier, 49 years of age, has been a member of the Society since 1932, and a member of the ASME staff in various capacities for the past 11 years. He was elected Assistant Secretary in 1953 and advanced to the post of Deputy Secretary last December. He was graduated from Lehigh University in 1929 with the degree of Mechanical Engineering and received his Masters Degree from the same institution the following year. He was formerly associated with the Consolidated Edison Co. of New York.

## Future Meetings of NWSA

Raymond P. Tarbell, President, Scott-Tarbell, Inc., Cleveland, Ohio, who was elected President of the National Welding Supply Association at the Thirteenth Annual Convention in Washington, D. C. in May, has just announced the schedule of Association Zone Meetings for 1957, as follows: Central Zone, Sheraton-Gibson Hotel, Cincinnati, Ohio, September 12–13, 1957; Eastern Zone, Commodore Hotel, New York, N. Y., September 16–17, 1957; West Central Zone, The Cosmopolitan, Denver, Colo., November 11–12, 1957; Western Zone, Riviera Hotel, Las Vegas, Nev., November 14–15, 1957; Southeastern Zone, Atlanta Biltmore, Atlanta, Ga., December 2–3, 1957; and Southwestern Zone, The St. Anthony, San Antonio, Tex., December 5–6, 1957.

The Fourteenth Annual Convention will be held in the Americana, Miami Beach, Fla., Monday, Tuesday and Wednesday, May 5th, 6th and 7th, 1958.

## ASTM Elects New Officers

The American Society for Testing Materials announced the election of new officers at their 60th Annual Meeting, June 16–21, at Atlantic City, N. J. The incoming officers are: Richard T. Kropf, president; F. L. LaQue, vice-president; and as directors, Claude L. Clark, A. E. Juve, John H. Koenig, Rudolph Earl Peterson and Russell Wade Seniff, were elected to three-year terms in office.

## RWAA Elects New Officers

Walter A. Cox, general manager of W W Alloys, Inc., Detroit, Mich., was elected president of the Resistance Welding Alloy Association at the First Annual Meeting of the organization held in Detroit last week.

James A. O'Grady, President of Weldaloy Products Co., Van Dyke, Mich., was re-elected vice-president.

Current business was reported to be equal to or a little better than 1956, with a favorable outlook for the months ahead.

In addition to the collection and distribution of industry statistics for the benefit of Members, the RWAA is developing dimensional standards for industry products that will be of value to all segments of the resistance-welding industry.

## BWRA Opens New Lab

The British Welding Research Assn. officially opened its new metallurgical laboratory at Abington Hall near Cambridge, England, on July 23rd. The Rt. Hon. Lord Tedder, marshall of the Royal Air Force and chancellor of the University of Cambridge, presided at the opening. The new laboratory contains the latest welding processes and control tests on its 13,000-sq ft area.

## Welding on TV

On June 8th New York area televiewers had the opportunity to see a welding story on the program, "Men of Achievement." This particular program showed scenes on the application of semiautomatic inert-arc welding of aluminum and roll planishing of welds on aluminum cones and cylinders. Airline Welding and Engineering, a supporting company of the AMERICAN WELDING SOCIETY, was the basis upon which the entire story was focused. This program had been viewed previously in Los Angeles, San Francisco and Seattle. Airline Welding and Engineering is located in Hawthorne, Calif.

## Farrell Lectures to French Engineers

The American Section of the Société des Ingenieurs Civils de France held their tenth lecture of the current season at the French Institute in New York City on June 12th.

William J. Farrell AWS, chief application engineer and assistant to the vice-president of Sciaky Brothers, Chicago, presented a lecture, accompanied by slides and a film, entitled "Recent Developments in Resistance Welding." Mr. Farrell emphasized the growing importance of resistance welding in the "Jet Age."

## Distributor Holds Open House

R & R Welding Supply Co. held an open house on June 20–21 at their new quarters, University at First, Des Moines, Iowa. Included in the welding display were live demonstrations of oxyacetylene, metallic-arc, inert-arc,

submerged-arc, semiautomatic $CO_2$ and constant-voltage welding processes. Cutting machines were also in operation. Representatives from over fifteen manufacturers were on hand to demonstrate their products.

### Fabrication Forum

A "Fabrication Forum," sponsored by Whitehead Metal Products Co., Inc., featuring over 100 experts and technicians from leading manufacturers, was held June 4th, 5th and 6th to celebrate the opening of the company's new Windsor, Conn., warehouse.

The new 34,100-sq-ft office and warehouse, eighth in the Whitehead chain, is located on the Hartford-Springfield Expressway in the new Windsor Industrial Park. It will carry the full Whitehead line of corrosion-resistant metals and accessories.

The Forum gave metal fabricators in the New England area an opportunity to view demonstrations on such fabricating operations as machining, anodizing, bending, flame cutting, welding, casting and brazing.

### Nelson Appoints Distributors

Two new distributors have been appointed by the Nelson Stud Welding Division of Gregory Industries, Inc., Lorain, Ohio.

The Darbyshire Steel Co., 1900 East Paisano Drive, El Paso, will handle Nelson studs and stud welding equipment in southwest Texas. New agent in western Canada is William P. Somerville and Co., 1736 Hastings St., East, Vancouver, British Columbia, Canada.

### Executive Changes at Whitehead

Edward W. Lothman, vice-president of Whitehead Metal Products Co., Inc., has been elected a director of the company, T. M. Bohen, chairman of the board, announced today. At the same time he also announced the election of Richard W. Nuffort as secretary, Frank A. Fink as treasurer and John W. Bonnet as administrative assistant to the president and assistant secretary.

The changes, all of which are effective July 1st, are occasioned by the retirement on that date of Elmer W. Silver. Mr. Silver is vice-president, treasurer, a director and a member of the management committee of Whitehead.

### Research Expanded at Airco

Ground was broken at Air Reduction Co.'s research center at Murray Hill, N. J., for the two-story polymer laboratory. The new wing to the main building will house research devoted to the development of polymers primarily for paints, adhesives, plastics and coatings. The ceremony provided the additional occasion to celebrate Airco's tenth anniversary at the Murray Hill site.

Airco's recent trend into chemistry is a result of by-product research in acetylene, one of their principal, manufactured gases. Dr. George V. Slottman, vice-president of research, cited the perfection of the inert-gas shielded-arc process as a major advance in their own welding development.

Construction is expected to be completed by the end of the year.

At the ground-breaking ceremonies for the new addition to the research laboratory of the Air Reduction Co. in Murray Hill, N. J., are shown, left to right: Mayor C. P. Dean of Summit; Mayor Samuel Jones of New Providence; John A. Hill, president of Airco; Dr. G. V. Slottman, Airco vice-president—Research and Engineering; and Dr. L. I. Gilbertson, director of the laboratories.

### Duquesne Oxygen Unit Commences Operation

The world's largest single-unit oxygen-producing plant for steel-mill service has commenced operation at the Duquesne, Pa., Works of the United States Steel Corp., according to a recent announcement by Harvey B. Jordan, executive vice-president—operations.

Built, operated and owned by Linde Co., division of Union Carbide Corp., the oxygen plant has a rated capacity of over 500 tons of oxygen per day.

About 90% of the oxygen produced by the new plant is being utilized to increase output and reduce fuel consumption in the Duquesne Works' ferromanganese blast furnaces. Ferromanga-


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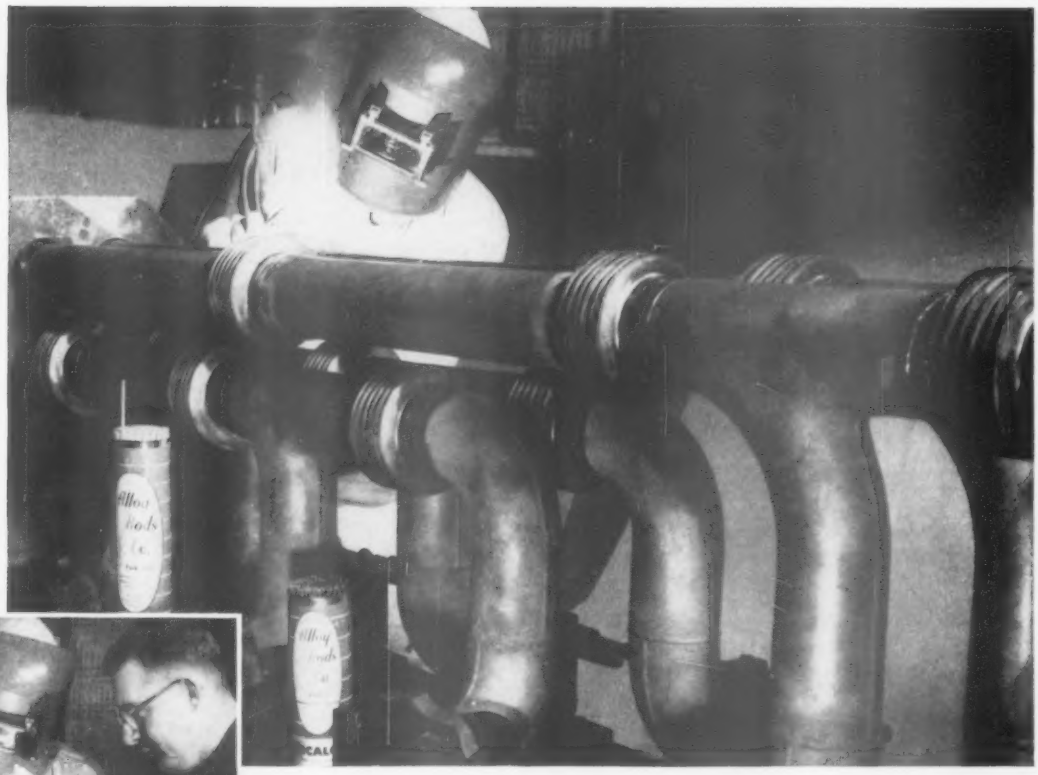

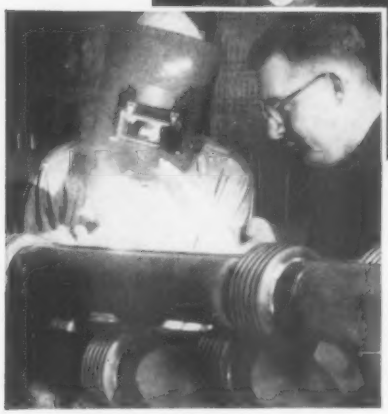

*Phil Hoener looks on as the weldor joins a bellows to the type 321 stainless manifold with Arcaloy type 347 electrodes*

**For maximum corrosion resistance at elevated temperatures . . .**

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# ARCALOY

## STAINLESS STEEL ELECTRODES

Highly corrosive diesel fumes at temperatures up to 1300° F. is the reason why Philip Hoener, Shop Superintendent, specified Arcaloy 347 AC-DC electrodes for the welds in this new stainless steel manifold for diesel engines.

Hanlon & Wilson Company, Pittsburgh, Pa., are the developers and manufacturers of this revolutionary, exceedingly superior manifold design which more than doubles the service cycle of railroad diesel engines.

The key to this development is a series of stainless steel bellows of unique design. Fourteen of these bellows working on a horizontal sleeve arrangement have eliminated failures caused by expansion and contraction, vibration, gas pressures and of course, corrosion.

There are 25 grades of Arcaloy stainless steel electrodes, in lime or AC-DC coatings, that will improve your product . . . provide a better quality weld metal. Write for a copy of bulletin AR-10, the selector guide to superior quality stainless steel weld metal.

Alloy Rods Co.

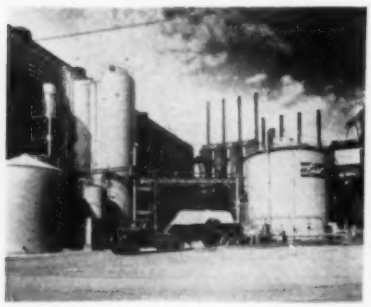
General Offices and Plant
Lincoln Highway West
YORK 3, PENNSYLVANIA

Pacific Coast Sales Office and Plant
750 Lairport Street
EL SEGUNDO, CALIF.

**NO FINER ELECTRODES MADE . . . ANYWHERE**

nese, a manganese-iron compound used as an alloying agent in steel making, is produced by essentially the same process used to make pig iron.

With additional oxygen entering the furnaces, the normal daily production of 700 tons of ferromanganese at Du-



quesne is expected to be increased by over 25%. At the same time, coke consumption per ton of ferromanganese will be reduced.

Enriching the air blast by 6% with oxygen will boost ferromanganese production by accelerating the smelting process. The flow of oxygen into the air blast is closely regulated to control the furnace temperature since excessive heat may damage the furnace linings.

Since fuel efficiency is improved by the addition of oxygen to the blast, less coke is burned for each ton of ferromanganese produced. Under ordinary operating conditions, ferromanganese furnaces consume over $2^1/_2$ times as much coke as pig iron furnaces—about 3400 lb per ton of metal as compared to 1300.

## "IRONWORKER"

**Here is the reason why this "ironworker" is so well-dressed: the occasion is the start of steelwork demolition of the Hotel Marguery on Park Ave.**

Shown here, making the first cut in one of the old columns, is W. M. Haile, now president of Linde Company, a division of Union Carbide Corp. UCC will erect a 52-story home office building on this site in New York City.

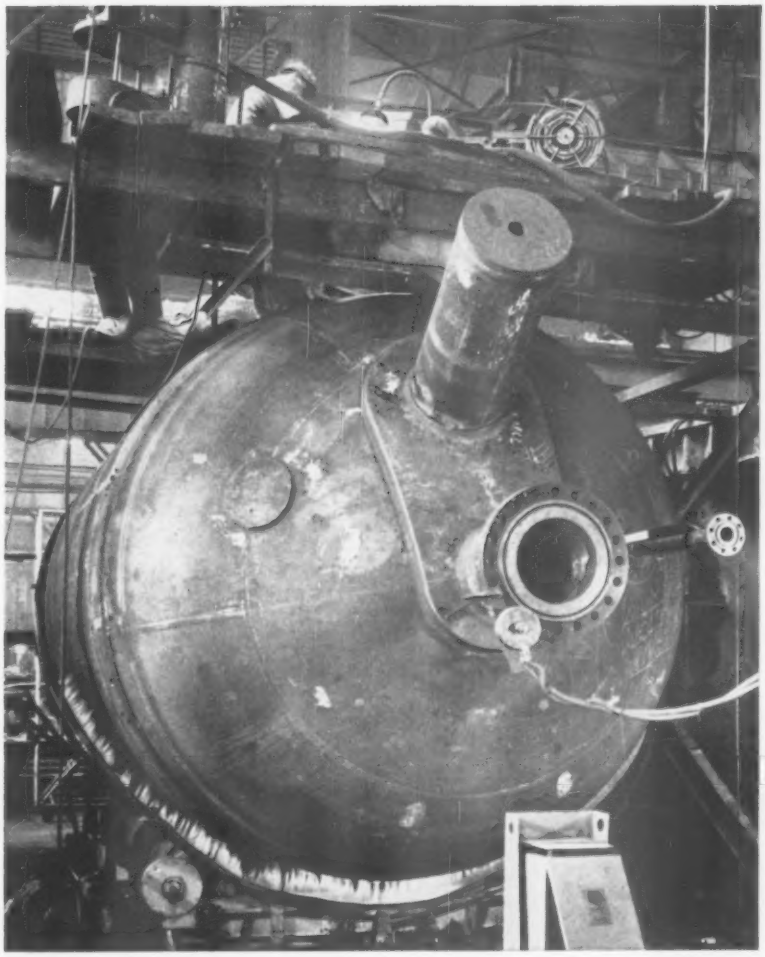
## "PLAYER PIANO" WELDING

Insert a roll of tape, set the controls and this machine automatically welds in less than one and a half hours as many as 1600 spots on a jet engine part at General Electric's plant at Everett, Mass. This machine is expected to save approximately $26,000 annually in the manufacturing of jet engines for defense. With the new machine, jet engine cylindrical parts can be welded in about one-quarter of the time it formerly required with a manually-operated welding machine. All directions and positions for the welding are programmed on a punched paper tape which automatically controls the positioning, indexing and welding cycle of the machine during the entire operation.

GOOD WELDERS DO BETTER WITH
ALL-STATE
ALLOYS AND FLUXES
They Save On:
• Preparation
• Dismantling
• Reassembly
• Cleanup
• Heat
• Time
Seldom cost as much as 1% of savings made!
All-State
HELPFUL HINTS
Look for the trade-mark at at your Welding Supply Distributor's. All metals. All methods. All-State is your assurance of these advantages when you buy. Ask for new Instruction Book on 62 alloys and fluxes.
ALL-STATE WELDING ALLOYS CO., INC., WHITE PLAINS, N. Y.

## AEC REACTOR

Recently the Atomic Energy Commission of the Department of Defense completed work on a $3,500,000 Army Package Power Reactor which is now being test operated at Ft. Belvoir, Va. The nuclear power plant—one of the Nation's first to go into service and the first of a series being developed for the U. S. Army—was built by ALCO Products, Inc., of Schenectady, N. Y., under a contract with the U. S. Atomic Energy Commission. It is the Army's first undertaking in the power reactor field. The net electrical output of the plant will be utilized to supplement the Ft. Belvoir power distribution system.



# When fabrication codes demand 100% X-ray inspection...

SPECIFY *Drawalloy* CORPORATION

## Stainless Steel Welding Wire

In hundreds of applications, *Drawalloy* wire has been put to the test . . . X-ray, dye check, pressure and service and with the same consistent result—OK as welded. That's why Frank Iapalucci, Manager of Welding Engineering for Baldwin Lima Hamilton, Eddystone, Penna., selected *Drawalloy* chrome-moly wire for the automatic welds on this reactor. The vessel is constructed of A 301-54T Grade B firebox quality steel ranging in thickness from 5-1/16" to 2-5/8". *Drawalloy* 1-1/4 Cr, 1/2 Mo wire was used for all submerged arc joints.

When inspection by X-ray is required, don't gamble . . . rewelding is expensive . . . specify Drawalloy "quality controlled" wire. *Drawalloy* stainless steel welding wire is produced to strictly controlled specifications to provide the right chemistry, finish and temper for smooth operation in your equipment and to provide X-ray quality welds.

Why not discuss your stainless welding wire needs with your *Drawalloy* Distributor or Representative . . . a man ready to help you. Bulletin 355-DC provides complete information on every grade of *Drawalloy* wire. Write to: Drawalloy Corporation, Lincoln Highway West at Alloy Street, York 13, Pennsylvania.

**DRAWALLOY**
**CORPORATION**
YORK, PENNSYLVANIA

**THE WIRE MILL FOR THE WELDING INDUSTRY — STAINLESS STEEL · HARD SURFACING · TOOL STEEL**

# PERSONNEL

## Marshall New Research Director

Dr. Shadburn Marshall has been appointed director of metallurgical research at Air Reduction's Central Research Laboratories, Murray Hill, N. J., it was announced by G. V. Slottman, vice-president of research and development.

Shadburn Marshall

Prior to joining Airco, Dr. Marshall specialized in materials application and process development for the fabrication of metals. Much of his work was with nuclear materials and fuel elements.

Dr. Marshall is the author of numerous technical papers published in various professional journals.

## Robert M. Briney Promoted

Robert M. Briney has been appointed president of Haynes Stellite Co., Division of Union Carbide Corp., it was announced today by Morse G. Dial, president of Union Carbide.

Mr. Briney started with the Corporation in 1924 in the Niagara Falls, N. Y., plant of Electro Metallurgical Co., a division of Union Carbide. He has held key positions with that division both in production and development at Niagara, as well as at Alloy, W. Va., and New York. In 1950, he was made vice-president in charge of wrought alloy products for Haynes Stellite Co., in Kokomo, Ind., and was transferred to the New York office of that division in July 1954.

Mr. Briney was born in Dayton, Ohio. He received a Bachelor of Science degree in chemical engineering from Purdue University in 1924.

## Commander Huester Transferred

Harry J. Huester, a member of 20 years standing of the AMERICAN WELDING SOCIETY, has been transferred from the Naval Air Station, Aeronautical Engineering Department, Jacksonville, Fla., to his new post at the Naval Air Material Center, Philadelphia Navy Yard.

## Howard Promoted

Donald B. Howard has been appointed Staff Metallurgist, Research and Development Department of the American Car and Foundry Division, ACF Industries, Inc., and will be assigned to the New York Office.

During his ten years with ACF at Berwick, Pa., he has devoted much effort to the evaluation of new welding materials and processes and their subsequent application in the railway equipment and Ordnance field. Prior to his association with ACF he was a metallurgist at the American Steel and Wire Division of United States Steel Corp.

Donald B. Howard

Mr. Howard was graduated from Colgate University in 1939. He is a member of the AMERICAN WELDING SOCIETY of which he is currently the District Director for District No. 2. He has served on the SOCIETY's National Board of Directors since 1952 as well as the following committees: Technical Council of the Board of Directors, Headquarters Housing Committee, Membership Committee, Section Advisory Committee, Educational Activities Committee (Sub Committee "A"), the Committee on Filler Metal as well as Special Committees on Membership Classification and Sustaining Membership. Mr. Howard is also a member of the American Society for Metals.

## Middaugh Promoted by Sylvania

The appointment of Kenneth F. Middaugh as plant manager in charge of weld[illegible] operations of Sylvania Electric Products Inc. has been announced by Merle W. Kremer, general manager of the company's Parts Division.

Kenneth F. Middaugh

In his new assignment, Mr. Middaugh, who previously was purchasing agent for the Parts Division, will be responsible for manufacturing operations at Sylvania's weld plants in Warren, Pa., and in Nelsonville, Ohio. He will continue to have his office at headquarters in Warren.

## Haberman and Jackson Appointed by Eutectic

Rene D. Wasserman, president of Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N. Y., announces two new appointments to the organization.

M. A. Haberman has been named manager of the plant office of Eutectic Welding Alloys Co. of Canada, Ltd., 3150 37th St., Ville St. Michel, Montreal. Mr. Haberman will supervise customer service and will be responsible for the conduct of the Eutectic Welding Institute courses at the Montreal plant.

Mr. Wasserman also announces the additional appointment of John E. Jackson as regional manager.

Mr. Jackson, a ten-year veteran in customer service at Eutectic's headquarters, will train and coordinate the activities of a group of district engineers. A graduate of the University of

Plant, Research Laboratories and World Headquarters

BETTER FASTER

Low Temperature EUTECTIC WELDING ALLOYS

STRONGER WELDS

# EUTECTIC Welding News

PUBLISHED BY EUTECTIC WELDING ALLOYS CORPORATION, 40-40 172 STREET, FLUSHING 58, NEW YORK, N. Y.

## XYRON 2-25 REPAIRS RR DIESEL ENGINE SAVES $10,800, WEEKS OF DOWNTIME

A large break in the first cylinder of a 600 horsepower diesel engine almost resulted in the loss of $10,800 by a Midwestern railroad. Attempts to repair the engine with conventional high heat welding materials failed because the block was thoroughly dirt and oil soaked and its tremendous size made pre-heating impossible.

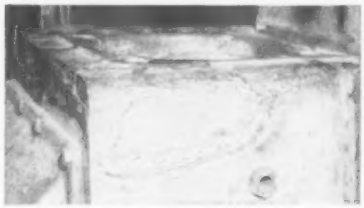
Fig. 1

The railroad's maintenance foreman was ready to recommend scrapping the engine when Eutectic's District Engineer suggested welding with patented Xyron 2-25, "Eutectic's" newest and most advanced electrode for all types of grey and alloyed cast iron. Xyron 2-25 is usable fast and cold and is the first non-cracking, porosity free, all position electrode for cast iron.

Fig.2

Repair was begun by veeing out all broken surfaces with Eutec-Chamfer-Trode, high speed gouging electrode for all metals. (Fig. 1) Gouging with ChamferTrode provided a good surface for deposits of Xyron 2-25 and burnt out many of the impurities in the casting. After the broken parts were reassembled on the engine block, Xyron 2-25 was used to tack weld. (Fig. 2).

Welding machine was set at 100 amps, DC reversed. The weldor then used a stringer technique with short arc to deposit 2" passes of Xyron 2-25. Peening after each pass relieved stress and slag was easily removed.



Final results were excellent. Xyron 2-25 produced dense, smooth, porosity free deposits at lowest amperages. (Fig. 3) Fast repair with Xyron 2-25 saved railroad $10,800 replacement cost and avoided weeks of downtime. *(A-71)*

### HIGHEST STRENGTH JOINTS WITH EUTECTRODE 201

Welded with patented EutecTrode 2101, the aluminum tine joints on this cement block unloader are up to three times stronger than joints of conventional aluminum electrodes. Loads of close to a ton cause the tines to dip as much as eight inches without cracking. EutecTrode 2101 quickly fabricated the block unloader, produced smooth solid deposits with good color match and high resistance to corrosion. The first aluminum electrode with an extruded flux coating, EutecTrode 2101 does not spatter or fume, produces a quiet arc at lowest amperages. EutecTrode 2101 outperforms all conventional aluminum electrodes. *(A-72)*

### EUTECTRODE 680 AC-DC AVERTS 10 WEEK STOPPAGE

A Tennessee stamping plant faced an 8-10 week production stoppage because of a cracked shaft on a 340 ton press. Replacement was estimated at $15,000. But downtime was averted and replacement cost saved by using EutecTrode 680 AC-DC and Eutec-ChamferTrode to repair the shaft at a cost of only $37 in materials. Eutec-ChamferTrode, high speed gouging electrode, was first used to vee out the crack, which extended 6" through the 12" shaft. EutecTrode 680, patented high tensile electrode for very high alloy and carbon steels, was then applied. Eutec-Trode 680 welds were applied at lowest amperages. *(A-73)*

**In answering industry's requests for technical data, Eutectic's research and engineering staffs help industry save thousands of dollars each year. Your questions, like these below, will be answered without obligation by Eutectic's Technical Information Service.**

**Q.** My company's welding manual makes reference to the use of solder in the repair of lamp socket contacts. EutecRod 157 with Eutector Flux 157 was recommended to us for this application. Will you advise? We would like to incorporate this information in our manual for future use. The fact that this soldering is performed by unskilled personnel should be considered.

**A.** EutecRod 157 is considered an ideal recommendation. Since this alloy has an extremely narrow plastic range, rapid solidification takes place, assuring a good build-up. It is therefore easier to handle by the unskilled. Deposits are harder and have higher electrical conductivity than conventional solders. This means greater resistances to pitting and general wear. Since the alloy has a higher solidus temperature, the possibility of plasticizing the build-up if accidental arcing occurs is virtually eliminated. Contacts also will remain bright and clean since EutecRod 157 does not contain lead or other elements than darken with age. Melting point is approximately 430° F. Electrical conductivity is 18 percent.

**Q.** What is the electrical resistance of EutecRods 180, 800, and 1804?

**A.** Electrical resistivity of all three is almost identical in that values of 23/24 microhms per cubic centimeter are obtained on all tests.

Eutectic Welding Alloys Corporation
40-40 172nd Street, Flushing 58, N.Y.

Gentlemen:

I would like further free information on the following:

☐ A-71 ☐ A-72 ☐ A-73

☐ Free 170 page pocket Welding Data Book.

Name _____

Business Address _____

City _____ State _____

"EUTECTIC" WELDING HEADLINES - TIME - MONEY - MACHINERY SAVERS

Kentucky, he is a member of the AMERICAN WELDING SOCIETY.

## Konkol Appointed by Sylvania

The appointment of George Konkol to the newly created position of manufacturing manager in charge of wire, weld and metal stamping operations for Sylvania Electric Products, Inc., has been announced by Merle W. Kremer, general manager of the company's Parts Division.

In his new assignment, Mr. Konkol will be responsible for manufacturing operations at Sylvania's weld plants in Warren, Pa., and Nelsonville, Ohio, metal stampings plant in York, Pa., and wire plant in Warren.

## Lenhard and Lunger Promoted by Airco

Effective July 1, 1957, R. E. Lenhard, president of the Ohio Chemical & Surgical Equipment Co., a division of Air Reduction Co., Inc., will become executive vice-president of the major division of Air Reduction, the Air Reduction Sales Co., it was announced by John A. Hill, president of the corporation. Also effective the same date, W. A. Lunger, vice-president of the Ohio Chemical division, will be appointed president of that division.

## Price and Lindsay Promoted by Liquid Carbonic

The Liquid Carbonic Corp., Chicago, has announced the appointment of William E. Price as sales manager, Industrial and Medical Equipment. In his new post, Mr. Price will direct sales promotion on the various lines of apparatus and supplies through their district sales offices and network of distributors.

The same firm has also announced the appointment of Donald R. Lindsay as assistant to the sales manager, Industrial Gas Division. Mr. Lindsay became associated with Liquid Carbonic in 1948.

## LeCompte Appointed By Shieldalloy

Thomas H. LeCompte has been appointed as sales specialist in the specialty steel and alloy field, according to an announcement by S. W. Madsen, vice-president, Shieldalloy Corp., Newfield, N. J. Mr. LeCompte will direct sales of special alloys for tool and stainless steels, chromium metal and master alloys for vacuum-melted superalloys, and master alloys for titanium additions in the production of titanium alloys.

Before joining the Shieldalloy organization, Mr. LeCompte was employed in the field of steel sales for a period of seven years. Prior to this, he was connected with the Lackawanna Plant of the Bethlehem Steel Co. Mr. LeCompte received a B.S. in metallurgical engineering from the Michigan College of Mining and Technology.

## Coughlin Appointed Sales Manager

James P. Coughlin has been appointed general sales manager, Cushioning Products Div., Armour and Co., Alliance, Ohio. He will supervise the division's

James P. Coughlin

sales for the automotive and transportation industries, the furniture and upholstery industries, packaging products and Armofoam products.

Formerly, he was assistant to the president, Eutectic Welding Alloy Corp. and in 1953 he was division manager of welding, Westinghouse Electric Corp. in Buffalo, N. Y.

Mr. Coughlin is a graduate electrical engineer from the University of Missouri and completed postgraduate work at the Carnegie Institute of Technology and the University of Pittsburgh.

He is a member of the AMERICAN WELDING SOCIETY.

## Mortrud Joins Burdett Oxygen

The Burdett Oxygen Co. of 3300 Lakeside Ave., Cleveland, Ohio, has announced the appointment of A. T. (Mort) Mortrud as manager of the Arc Welding Division. As manager, Mr. Mortrud will supervise the sale of General Electric arc-welding machines, arc-welding electrodes and arc-welding accessories. Mr. Mortrud joins Burdett Oxygen with more than twenty years of service in the arc welding business. During this time he was associated with Hobart Brothers and Marquette Manufacturing. He served six years as district manager for the Harnischfeger Corp., and then was

A. T. Mortrud

promoted to manager of Cleveland sales for that firm. Mr. Mortrud is a member of the AMERICAN WELDING SOCIETY.

## Onders and Ghastin Appointed by Wall Colmonoy

According to an announcement by W. P. Clark AWS, vice-president for Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich., two new appointments have been made in the company's sales organization.

Charles S. Ghastin will represent the

Charles S. Ghastin

John R. Onders

LINCOLN IDEALARC WELDERS
OFFER EITHER DC OR AC
WELDING CURRENT
AT THE FLICK OF A SWITCH.
CAPACITIES FROM
180 AMPS. TO 500 AMPS.
OPERATE ON SINGLE PHASE
POWER... AND COST NO MORE
THAN ORDINARY DC WELDERS

300, 400 and 500 Amps. models (left)

180, 250 Amps. models (below)

**BULLETIN SB-1350**
contains construction details and specifications. Bulletin SB-1343 tells what it will do for you. Write for them.

**THE LINCOLN ELECTRIC COMPANY**
Dept. 1931 • Cleveland 17, Ohio
*The World's Largest Manufacturer of Arc Welding Equipment*

**MANUFACTURING RESEARCH ENGINEER**

• *Welding* •

Welding section of Manufacturing Research & Process Department has an excellent opportunity for a college graduate with BS in engineering or science, plus 3 years experience in welding. The applicant selected will conduct research and development programs in welding; also act as welding consultant to engineering, and apply welding processes for production. Experience in aircraft manufacturing preferred.

Salary commensurate with experience and ability to work with high degree of independence.

Among other advantages, Republic offers a comprehensive benefit program including company-paid hospitalization, surgical, accident and life insurance, tuition (²/₃), 2-fold pension plan, individual merit rated increases and many other benefits.

*Send resume in confidence to:*
MR. PAUL HARTMAN
*Employment Department*

REPUBLIC AVIATION
Farmingdale, Long Island, N. Y.


company in the New York area. Mr. Ghastin was recently a district engineer for a manufacturer of welding rods and electrodes.

John R. Onders has been named to the Pittsburgh sales force. Prior to joining Wall Colmonoy, Mr. Onders was general manager of a custom welding house.

## EMPLOYMENT SERVICE BULLETIN

### Positions Vacant

Excellent opportunity for young engineer to join national staff of American Welding Society in New York City. Recent promotion creates vacancy for assistant to technical secretary. Responsibilities to include representation on technical committees, research on technical data, editing of standards, answering technical inquiries from industry. Applicant must have degree in engineering, with at least three years experience, preferably in welding or allied fields. Salary commensurate with qualifications and experience. Send résumés to Technical Secretary, 33 W. 39th St., New York 18, N. Y. All replies will be held in confidence.

V-343. Engineer. Age 28 to 33, with


**2 RESEARCH METALLURGISTS**

Masters or Ph.D. degrees preferred. 25 to 35 years of age. Work in applied research, dealing with welding of ferrous and non-ferrous alloys, investigation of service problems, and selection of materials of construction.
Applicants should have experience in the application of metallurgy to production problems.

C F BRAUN & CO
Alhambra, California
Engineers and Constructors

**NOW READY FOR PRODUCTION!**

*The All-New*
**B-58**
*America's FIRST Supersonic Bomber*

**• Welding Engineers**
**• Metallurgists**

Recent graduates and non-graduates with sufficient experience to develop metallurgical processes and solve production problems in welding and heat treating of ferrous and non-ferrous metals for the all-new B-58. Work in America's largest and finest aircraft manufacturing facility, enjoy pleasant suburban living with metropolitan educational and cultural facilities, salary and employee benefits that are tops in the industry. With nearly half-a-hundred Air Force contracts on hand, your future is *NOW* . . . at Convair!

*Send resume of training and experience to:*
MR. B. R. TOUDOUZE
**CONVAIR**
**FORT WORTH**
FORT WORTH, TEXAS
CONVAIR IS A DIVISION OF GENERAL DYNAMICS CORPORATION

**WELDING ENGINEER**

- Experienced in resistance, arc, and gas welding. Manual, semi-automatic, and automatic.
- Must be qualified to determine process, specify equipment, and ability to apply same for successful conclusion on high production.
- Primarily steel stampings and assemblies.
- Heavy machinery plant employing 2,500. Location—Mid-West

*Write qualifications and present salary.*

**Write V-345, The Welding Journal.**

Get the BEST for LESS
Get
"ANTI-BORAX" FLUXES
Fully Guaranteed
SAFE—NON-TOXIC

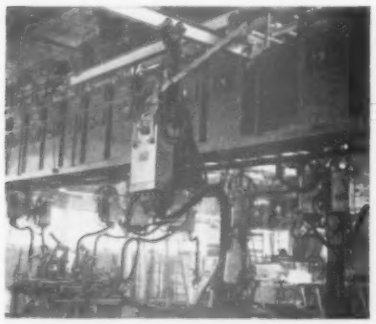
No. 1 Cast Iron Welding Flux
No. 2 Brazing Flux
No. 4 "Braz-Cast" Flux for bronze welding cast iron
No. 8 "ABC" Sheet Aluminum Flux
No. 16 Silver Solder Paste Flux

*Send for complete Folder and Samples*

Mfg. by
ANTI-BORAX COMPOUND CO. INC.
Fort Wayne 9, Indiana

Installation of NEMA type N²X Robotron 361C Resistance Welding Controls at International Harvester Plant, Chatham, Ontario. Equipped with 200 amp., 2-pole 600 volt isolation switch, and special Safety-Lock doors.

# Production welding operations are big factor in International Harvester quality control



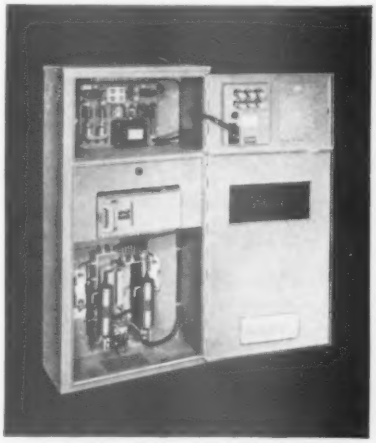
Another view of installation showing close-up of welding transformers and portable guns.

### Canadian Plant Uses Robotron Timers on Resistance Welders

Modern production equipment is one of the important reasons behind International Harvester's world famous reputation for quality products. At IH's Chatham, Ontario plant, Robotron resistance welding controls are playing an important part in maintaining this high level of quality in IH trucks for the Canadian market. Robotron precision timers provide efficient, economical control for the scores of resistance welders at work on the company's production line.

Varied resistance welding problems can be solved with one master unit through interchangeable "plug-in" type components . . . holding costly downtime to a minimum, eliminating equipment tie-ups and reducing obsolescence. The design simplicity of Robotron controls allows maximum on-the-job versatility.

To improve product quality and reduce production costs in *your* operations, let Robotron's experienced staff team up with you in the practical solution of control problems. Discuss your requirements with a Robotron field representative.



Series 361C Resistance Welding Control, consisting of Model 3B08E-C NEMA 3B "Fail-safe" tube firing timer, isolation switch, and 600 amp. ignitron contactor.

THE FINEST IN INDUSTRIAL ELECTRONICS

**Robotron CORPORATION**

21300 WEST EIGHT MILE, DETROIT 19, MICHIGAN

INDUSTRIAL ELECTRONICS FOR YOU...FROM ROBOTRON —A new bulletin available on request. Write for your copy today.

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experience in the gas welding, cutting and pressure regulator fields to assume duties as assistant chief engineer in the design of new products and the development of new manufacturing processes.

Established, growing Cleveland manufacturer of gas welding and cutting equipment. Send complete résumé indicating salary desired.

V-344. Director of technical training—welding, brazing, soldering. Alloys company with international distribution has unusual opening for an excellent instructor skilled in joinery techniques and metallurgy of welding processes. Position requires sales sense, speaking ability, extensive travel, mature judgment, and acceptance of responsibility. Primary task is training of company representatives and distributors, which includes conduct of clinics and demonstrations and speaking before technical and operating groups. Salary plus expenses.

## Glidden Joins Metalweld

Kenneth G. LeFevre, vice-president of the Protective Coatings Division of Metalweld, Inc., applicators of tank linings, has announced that William E. Glidden, formerly founder and president of Glidden Coating Co. in Pitman, N. J., has recently become associated with Metalweld in Philadelphia.

Prior to forming his own company in 1948, Mr. Glidden was associated with Metallizing Engineering Co. as a development engineer and a sales engineer.

William E. Glidden

He holds a B.S. in mechanical engineering from the University of Iowa (1932) and was one of the pioneers of the process of metal spraying. He joined Metallizing Engineering in 1935 and, except for a brief tenure in another company and a three-year tour of duty in the U. S. Navy during World War II, Mr. Glidden remained with the metallizing firm until forming his own company nine years ago.

He is a member of the AMERICAN WELDING SOCIETY, the National Association of Corrosion Engineers and the Society of the Plastics Industry.


**MEMBERSHIP IN THE AMERICAN WELDING SOCIETY**

helps you improve your product, increase your production and lower your welding costs. You'll have for your own use latest available welding "know-how", including the Society's Welding Journal and Welding Handbook. How you can join the Society and take advantage of its many benefits is explained in descriptive literature available.

For further details write to

AMERICAN WELDING SOCIETY
33 West 39 Street
New York 18, N. Y.


## Moeller New Sales Manager

John W. Moeller has been appointed sales manager of the Welding Products Division of California Alloy Products Co., 6438 E. Corvette, Los Angeles, it has been announced by Hugo Hiemke, president of the firm.

John W. Moeller

Mr. Moeller brings to California Alloy Products considerable background and experience in the welding field, having been manager of the welding division of Pacific Metals Co. for the past 11 years, and welding consultant to a number of large construction and engineering firms.

Mr. Moeller's responsibility will be to promote sales and application for welding electrodes and machines.

He is a member of the AMERICAN WELDING SOCIETY.

## OBITUARY

### Lee H. DeWald

Lee H. DeWald, 51, chief metallurgist for National Cylinder Gas Co., Chicago, died the night of May 30, 1957, at his home in Aurora, Ill. He had been with NCG since August 1948 and worked out of the company's 19th St. plant in Cicero.

Lee H. DeWald

Mr. DeWald received his B.S. and M.E. degrees from the Missouri School of Mines and spent several years as development engineer at the Western Electric Co. He later became metallurgical engineer for Goldsmith Brothers Smelting and Refining Co. and held a part-time staff position at Northwestern University during this period. From 1937 to 1944 he joined the technical staff of Fansteel Metallurgical Corp. and its carbide-producing subsidiary, Vascolor-Ramet Corp. In 1944 he supervised the installation of a cemented carbide manufacturing unit for Archer and Smith Ltd. in Lexington, Ky. A year later he joined the metallurgy department at Massachusetts Institute of Technology.

Mr. DeWald was a consultant on cemented carbides and powder metallurgical problems for many years and supervised special government-sponsored researches on refractory materials. He was well known for recent research and lecture activity on $CO_2$ and inert-gas arc-welding processes.

Mr. DeWald was a member of the AMERICAN WELDING SOCIETY.

# NEW LITERATURE

## Welding Positioners

Aronson Machine Co., Arcade, N. Y. announces the availability of a booklet on floor turntable welding positioners, ranging in capacity from 1000 to 120,000 lb.

According to the manufacturer, Aronson floor turntables afford industry with low-cost high-precision means of rotating workpieces about a vertical axis. The seven models described in the booklet indicate various methods in which these positioners can be utilized in burning, grinding, X-ray and welding.

For your free copy, write to the above source and request Bulletin No. FT57.

## Literature from BWRA

Several new booklets are available from BWRA on the following subjects: *Jigs and Positioners* (5/—), 30 pages; *Heat Treatment of Welded Constructions* (5/—), 28 pages; *Resistance Welding* (7/6), 46 pages; *Arc Welds in Mild Steel—Production and Inspection* (2/6), 12 pages; and *Design of Welded Joints* (7/6), 48 pages. Also available from the same source is a revised edition of the BWRA wall chart which depicts faults encountered in metal-arc welding. The prices are 5/— and 11/— for unmounted and mounted copies, respectively. To order your booklets or charts, write to the British Welding Research Assn., c/o 29 Park Crescent, London W. 1, England. Mailing charges will be postpaid.

## Welding News

The second quarter 1957 issue of the Ampco Welding News, published by the Weldrod Department of Ampco Metal, Inc., is available for distribution.

This issue cites several detailed instances in which savings resulted from the use of bronze electrodes and filler rod. The lead article describes the rebuilding of badly worn centrifugal-mold shaker pistons with Ampco-Braz No. 1 filler rod. Other articles are devoted to the fabrication of dynamite-mixing bowls, salvaging of drop-forge hammer columns, overlaying of large conveyor-belt sprockets, and the "capping" of steel gear teeth.

Free copies of this publication may be obtained by writing to Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis.

## Hard-Surfacing Booklet

Metal & Thermit Co., Rahway, N. J., offers a new 20-page booklet about a new line of Murex Hardex hard-surfacing electrodes. The electrodes best suited to different hard-surfacing applications are charted in the booklet. Information is also furnished on how to decrease porosity, cracking, penetration and weld metal dilution with these low-hydrogen electrodes.

According to manufacturer, physical and chemical properties of typical deposits for each of the 16 electrodes now included in Metal & Thermit's new hard-surfacing line are described. With low-hydrogen coatings, the electrodes are engineered to improve wear characteristics under severe service conditions.

The wide selection permits close matching of weld metal to requirements for wear resistance. A free copy of the new booklet can be obtained by writing to Metal & Thermit Corp., Rahway, N. J.

## Film Catalog

A booklet entitled "Westinghouse Sound Films" is now available from Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa. The booklet is a catalog of forty-seven general information films, product-information films and training films available without charge.

Included in this group is a ten-minute film entitled "Metal Miracles,' which depicts brazing by the electric-furnace method.

For your free catalog, write for booklet B-7077 at the above address.

## Wall Charts

Two new two-color wall charts, designed for technical schools and plant-training programs in the practical aspects of torch and arc welding are now available from the Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, New York, N. Y.

The manufacturer states that each chart, measuring 22 x 34 in., is designed to fit into welding-training programs by providing students with graphically clear illustrations of correct arc and torch-welding procedures.

The Torch Applications chart (TIS 2690) explains the meaning of low-temperature welding, examines the good and bad of common joint designs, and the purposes for which thin-flowing and bead-forming alloys are designed.

The Metallic-Arc Applications chart (TIS 2689) explains the benefits of low-heat input, particularly the avoidance of cracking, hardening and embrittlement in the weld zone.

Either or both charts are available from the Technical Information Service, Eutectic Welding Alloys Corp.

## Welding News

Volume XIV, No. 2, Hobart Arc Welding News, a 28-page booklet of photographs and articles on welding from all over the world, is now available. Copies are mailed free of charge to anyone interested in welding.

Many of the articles feature time and money saving applications. For your copy, write Hobart Brothers Co., Troy, Ohio.

## AC-DC Welders

Four-page bulletin 1350, recently issued by Lincoln Electric Co., Cleveland 17, Ohio, describes 300-, 400- and 500-amp combination welding-power sources for ac or dc. Two pages are confined to various construction details, such as arc stabilization, single-phase operation and low-voltage contact. Another page describes the specifications to which these units conform. For your free copy, write to the manufacturer at the above address.

## Welding of 4130 Steel

Reprints of the paper "Gas-Shielded Consumable-Electrode Welding of 4130 Steel," as published in THE WELDING JOURNAL, have been made available by Air Reduction Sales Co.

The paper discusses, among other topics the testing of various wire electrodes of standard AISI low-alloy analyses with controlled phosphorus and sulphur contents, and compares the hardenability characteristics of the weld metals with those of the low-alloy base metals.

For a copy of this illustrated paper, write Air Reduction Sales Co., a division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y. Specify form ADR 112.

## Stud Welding

Complete information on stud welding equipment, including a trouble-shooting chart with procedures for correcting unsatisfactory conditions, is contained in a new Operation Manual, No. 5, now available from the Nelson Stud Welding Division, Gregory Industries, Inc., Lorain, Ohio. The manual may be obtained in either desk or pocket size.

An important new section of the manual is devoted to welding of large diameter studs, first made possible on a commercial scale by Nelson's new NS-9 stud welding gun. The manual provides full information on disassembling, assembling and maintaining Nelson equipment.

## Resistance Welding Controls

New Bulletin SP-19, the Taylor-Winfield Corp., Warren, Ohio, describes precise welding controls using Dekatron tubes in counting circuits that control welding time. The new controls improve the consistency of weld time longer than 15 cycles. Block and schematic diagrams illustrate the purpose and operational principles of the new controls.

For your copy write to the manufacturer at the above address.

## Face-Shield Windows

According to the manufacturer, a new means of heat forming face-shield windows, giving them permanent curvature to fit the inside radius of the spark deflector, has been developed by American Optical Co. Chief advantage is reduced pressure on fasteners, decreasing wear of fastener.

For full information, write for Brochure S-2141A, American Optical Co., Safety-Sun Glass Division, Southbridge, Mass.

## Arc-Welding Data

The Reid-Avery Co., Inc., has made available three new bulletins: AW 100—"Automatic Welding Wire for Submerged Arc Welding"; AH 200—"Equipment for Automatic Welding"; and 151—"Low Hydrogen Iron Powder Electrodes." Also available is a data sheet presenting the advantages of "Raco 6011" iron-powder electrodes.

For your free bulletin, write on company letterhead to Reid-Avery Co. Inc., Dundalk, Baltimore 22, Md.

## Automotive Welding

A 28-page "Special Automotive Issue" of Eutectic's semi-monthly Technical Information Digest is now available free from Technical Information Service, Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, New York, N. Y.

Sections of the new manual treat body work, salvaging castings, repair of mechanical parts and salvaging ornaments and accessories. The trend to customizing in automotive shop work is discussed and special welding techniques provided. The manual features welding techniques and procedures for metals such as aluminum and magnesium which are now more widely used in cars and trucks.

When writing for your free copy from the above source, specify booklet TIS 2822.

## Brazing Alloys

A two-page Engineering Data Sheet in color (No. 16) covering specifications for the full range of Nicrobraz high-temperature brazing alloys is now available from Stainless Processing Division of Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

Eleven of the manufacturer's Nicrobraz alloys are listed. For each is given nominal composition, solidus temperature, liquidus temperature, brazed-joint ductility, recommended brazing temperature and recommended atmospheres. A remarks column highlights important features and recommended applications for each brazing alloy.

BRAZING MATERIAL COSTS CUT 24% to 38%

NEW PHOS-SILVER-6M developed by Westinghouse SAVES $1.00 OR MORE PER POUND!

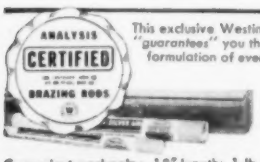
There is now a brazing alloy *proving* itself *superior* to brazing materials costing *3 to 4 times as much!*

It is the new Phos-Silver-6M—made by *extrusion* methods!—*blanketed* under *inert gas!* This eliminates the oxides that cause most brazing troubles. And produces *new versatility* in a brazing rod, with *exceptional* flow characteristics, *remarkable* ductility, and *unsurpassed* appearance of the finished work!

Moreover, Phos-Silver-6M (as *all* the new Westinghouse alloys), has been proved throughout stringent laboratory and shop tests, toughest production runs! Then, is now ANALYSIS CERTIFIED!—*assuring you* the *same consistent, best possible* brazing results!

Order *trial* packages *now!* You'll *standardize* on Westinghouse Brazing Materials *tomorrow!* J-22082-A

YOU CAN BE SURE...IF IT'S Westinghouse




This exclusive Westinghouse Seal "guarantees" you the correct formulation of every rod!

Convenient packaging, 18" lengths, 1-lb and 5-lb tubes. Standard 25-lb package, 36" lengths.

Select from the Westinghouse MOST COMPLETE LINE OF BRAZING MATERIALS IN THE INDUSTRY!

Phos-Copper®, Phos-Silver #2, Phos-Silver*, Phos-Silver-6M, Phos-Silver-15. These round, extruded rods give approximately 20% *more feet per pound* than square rods of the same diameter! (Same alloys also available in rod form, wire in coils, or rings.)

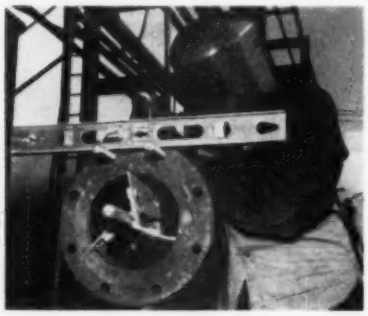
POWER-UP with Westinghouse *advanced* brazing materials!

*Trade-Mark

METAL & THERMIT CORPORATION
GENERAL OFFICES: RAHWAY, NEW JERSEY
MUREX® Electrodes Mild Steel, Low Alloy,
Stainless, Aluminum Bronze, Cast Iron, Aluminum
also HARDEX—new low hydrogen, hard surfacing electrodes
WELDING MACHINES
AUTOMATIC — constant voltage, for semi- and full-automatic welding
MANUAL — light or heavy duty, portable or stationary
ACCESSORIES Holders, helmets, gloves, cable, etc.
fine quality, prompt service— local rep's phone
A B C D E F G H I J K L M N O P S T U V

## Pipe Fabrication Tool

Bulletin No. 57 of the Line-O-Tool Co., 1927 Bank of the Southwest, Houston 2, Tex., describes a new tool for use in fabrication of pipe, utilizing weld neck flanges or stub ends. Tool is inserted into pipe and flange or stub end placed on projecting end. Few turns



of the mandrel bring blades into contact with pipe and fitting ID's. Three-blade design assures positive line-up of internal surfaces. Available for pipe sizes from 3 to 20 in. in 3 units: 3–4 in., 6–10 in., 12–16–20 in. Blades are interchangeable for 6–20 in. sizes. Tool can also be used as a centering device for grinding bevel on alloy tubing.

## Flash-Butt Welding

The Taylor-Winfield Corp., Warren, Ohio, describes new hydraulic controls for use with flash-butt welding machines on a wide variety of flash welder applications in their new Bulletin SP-4A. The bulletin, free on request, describes manual, semiautomatic and fully automatic operation. Included are schematic drawings of control linkage and hydraulic circuits, and oscillographs of resulting upset speed.

## Portable X-Ray Unit

The Balteau Electric Corp., New and Meadow Sts., Stamford, Conn., announces publication of literature describing a 200-kv portable X-ray unit, known as Baltospot 200. According to the manufacturer, the unit will X-ray up to 3 in. of steel, whereas the total weight including handles is 85 lb. Contact the manufacturer at the above address for your free copy of the literature, "Baltospot 200."

## Automated Welding

A four-page, $8^1/_2$ x 11-in., two-color folder which includes three designs and applications of unique automated welding machines and automation machines and, according to the manufacturer, how they solve specific problems and reduce both part and equipment costs is now available from Expert Die & Tool Co., 17144 Mt. Elliott Ave., Detroit 12, Mich.

An automated welder that combines both assembly and welding operations is described in the illustrated folder.

General purpose automated welding machines are also described.

## Nuclear Welding

Welding for Nuclear Pumping Applications, an 11-page illustrated report by F. R. Drahos, AWS, of the Byron Jackson Division of Borg-Warner Corp., is now available without charge. This report summarizes a presentation made to the Tenth Western Metal Congress at Los Angeles in March.

Welding requirements for nuclear service are outlined and 15 specific "do's and don'ts" for nuclear welding are prescribed. Photographs and drawings illustrate various nuclear pump welding designs and welding setups.

The report is available from Byron Jackson Division, Borg-Warner Corp., P. O. Box 2017A, Terminal Annex, Los Angeles 54, Calif.

## Tungsten-Arc Welding

The complete line of equipment designed for use in applications of Air Reduction's tungsten-arc Heliweld process is illustrated in a new 20-page catalog now available.

Catalog 2300, entitled "Heliweld Equipment" discusses the advantages of the Heliweld process and the factors which determine equipment selection. It contains information on various types of manual, semiautomatic and automatic equipment, and on accessory devices such as the arc starter, high-frequency oscillator, control panel and filler wire feeder.

A copy of the catalog may be obtained by writing to Air Reduction Sales Co., a division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y.

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# REVIEWS
### OF NEW BOOKS

## Manufacturing Processes

*Manufacturing Processes*, 4th Edition, hard-bound book, 612 pages, copiously illustrated and indexed. Price $8.00. Authored by Myron L. Begeman, professor of mechanical engineering at the University of Texas. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y.

This latest edition of Prof. Begeman's book contains 25 chapters, each one devoted to a particular process in the structure of manufacturing. Chapter 9 treats, in 43 pages, the part of welding in this structure, surveying the basic processes and terminologies available. The end of this chapter, as is the case with all chapters in the book, lists quite a few questions pertaining to the material.

The 4th edition, less descriptive than previous editions, places greater stress on principles and materials. New topics discussed include electroforming, metal-coating processes, electro-spark and ultrasonic machining, chem-milling and automation. There are 166 new illustrations, 89 of which are line diagrams. In addition, the photographic illustrations have been revised to show modern equipment.

## Tool Design

*Tool Design*, by Cyril Donaldson and George H. LeCain, 2nd Edition (1957). Price $6.75. 557 pages, 6 by 9 in. Hard cover. Published by McGraw-Hill Book Co., Inc., 330 West 42 Street, New York, N. Y.

This textbook was written at the Rochester Institute of Technology as part of its program for developing teaching materials which are practical in nature and closely related to the actual requirements of industry.

Chapter 7, entitled "Welding," is 77 pages in length and briefly describes the basic processes of welding and various types of flame processing. The major portion of the chapter is a comprehensive coverage of welding symbols. Ten questions and eight problems are listed toward the end of the chapter.

An attempt is made in this text to broaden the bases of study as much as possible, and for this reason, topics that may be dealt with in other courses, such as springs, welding and tolerances, are included in so far as they apply to tool design.

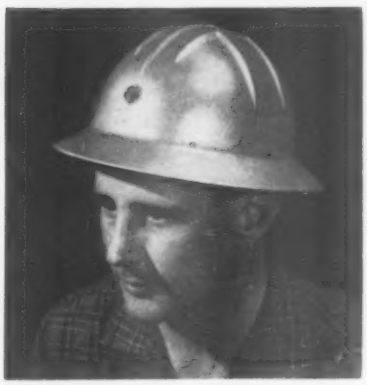
In this second edition the material on punches and dies, theory of cutting tools, jigs and fixtures and screw machines has been rewritten and expanded. The section on tool materials has been revised, and a special table aids the beginner in choosing materials at the beginning of a design.

The large number of questions, problems, drawing assignments and references makes this book valuable for the classroom or for individual home study.

# NEW PRODUCTS

## Aluminum Safety Hat

The "Alumihat," an aluminum safety hat, exceeds Federal Specifications for construction workers' hats, including both impact resistance (drop ball test) and penetration strength (plumb bob



test), passing all requirements except for insulation resistance, according to the manufacturer.

The six-point suspension headgear is a soft and pliable unit, shock absorbent and comfortable. It is buttonholed inside the hat shell for easy removal. The headband with clearly marked hat sizes is the fastest and easiest to adjust. Chin straps and winter liners are available.

For further information, write to Jackson Products (Air Reduction Sales Co., a division of Air Reduction Co., Inc.), 31739 Mound Road, Warren, Mich.

## $CO_2$ Welding in All Positions

All-position welding of mild steel with carbon-dioxide shielding gas is now possible with the semiautomatic Fillerarc equipment for the consumable-electrode, gas-shielded welding process, according to an announcement by the General Electric Co.'s Welding Department.

No powdered flux of any kind is needed with this equipment. According to the manufacturer, vertical and overhead welds can be made without difficulty.

The use of bare filler wire and carbon-dioxide shielding gas simplifies operation and eliminates problems ordinarily related to slag inclusion, flux removal and recovery, according to department engineers. Deposition rates are greatly in-

creased over conventional stick electrode processes and other consumable-electrode methods.

Fillerarc power sources include a special reactor that controls current peaks when welding with carbon dioxide and mild steel. Constant arc length and constant voltage power sources are available. The Fillerarc wire drive unit can use wire as small as 0.035, which permits welding steel from $^1/_{16}$ in. to several inches thick.

Additional information may be had by writing to General Electric Co., Schenectady 5, N. Y.

## Rectifier Welder

Miller Electric Mfg. Co. Inc., Appleton, Wis., announces a small rectifier-type d-c welding power source for use in tungsten-arc inert-gas welding.

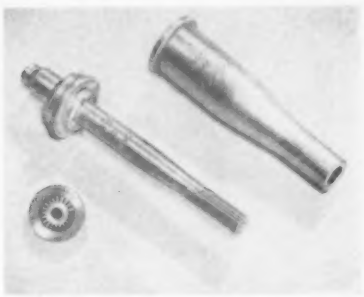
According to the manufacturer, the unit is particularly useful for welding

light-gage metals. Known as the Miller SR-10, its weight is 90 lb and its over-all dimensions are 14 x 22 x 15 in. Its initial impact is 15 amp with a downward range to 2.5 amp. Gas control valve and timer, available as extra equipment, provide for the use of a hand switch to initiate preflow of gas.

For more information, write to the manufacturer at the above address.

## Flame-Cutting Nozzles

The availability of two-piece nozzles for use in flame cutting has been announced by Linde Co., Division of Union Carbide Corp. Designed for flame cutting with oxygen and fuel



gases, each nozzle has from twelve to twenty small outlets for preheat gases, a feature the manufacturer claims will increase the rate of heat transfer and will produce a nearly solid ring of preheat flames.

These Oxweld nozzles are said to have a speed of leaving the cutting nozzle of 1200 fps compared to the conventional speed of 980 fps. The two pieces consist of a brass internal section with finely grooved slots for preheat gases and a heat-resistant copper cover.

For more information, write to the above company at 30 E. 42nd St., New York 17, N. Y.

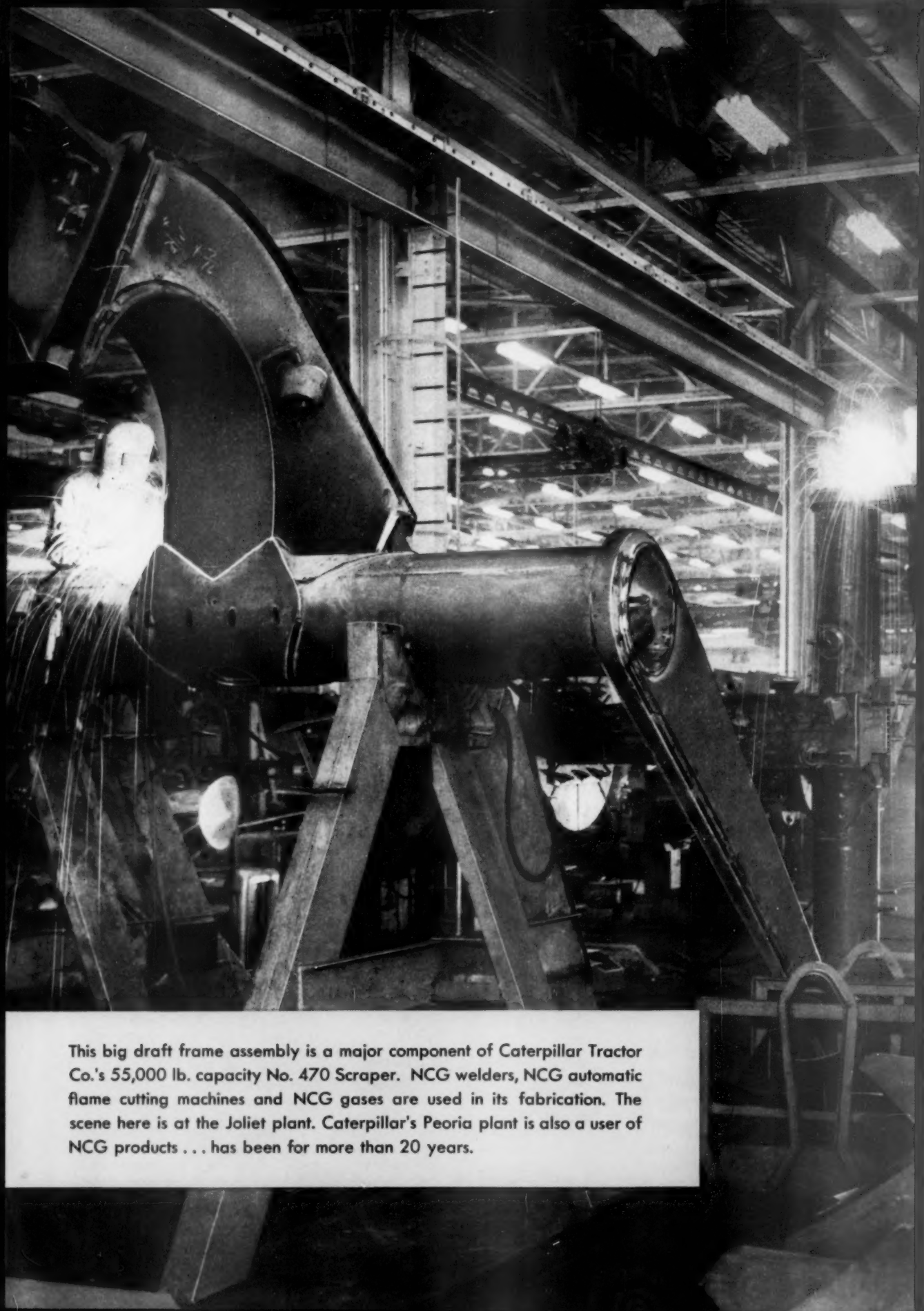
## E10013 Electrode

A heat-treatable all-position electrode for fabrication of chrome-moly steel and other high-tensile alloy steels has been announced by Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing, New York, N. Y.

The electrode, EutecTrode 71 AC-DC, conforms to requirements of an E10013 electrode, and is designed for low-alloy steels of the 4130, 4140 and 8630 grades.

Specific end uses for EutecTrode 71 AC-DC include fabrication of tanks, containers and vessels for high-pressure work. Aircraft landing gear, ribbing, framework, piping and tubing requiring high-tensile strength are other applications.

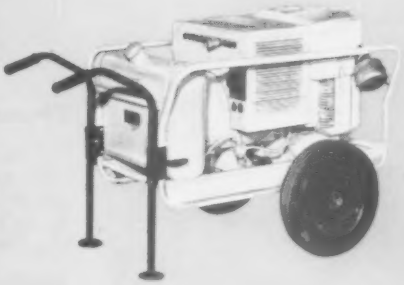
*(continued on page 850)*



This big draft frame assembly is a major component of Caterpillar Tractor Co.'s 55,000 lb. capacity No. 470 Scraper. NCG welders, NCG automatic flame cutting machines and NCG gases are used in its fabrication. The scene here is at the Joliet plant. Caterpillar's Peoria plant is also a user of NCG products . . . has been for more than 20 years.

**Sureweld**® A-C SHOP WELDERS—For general repair and light production work. 3 models.

**Sureweld** A-C INDUSTRIAL WELDERS—For heavy duty production welding. 10 models.



**Sureweld** D-C PORTABLE WELDER—Gas driven welder for field welding and maintenance work.

# Bring on ANY welding job!

**Sureweld** D-C RECTIFIER WELDERS—For manual and automatic welding—tungsten or metal electrode inert gas welding. 4 types, 15 models.

**Sureweld** INERT ARC WELDERS—For tungsten electrode inert-gas welding. 3 types, 31 models.

**Sureweld** A-C D-C WELDERS—For all arc-welding jobs—A-C or D-C of either polarity. 6 models.

Whatever the type you need, whatever the capacity, there's a *SUREWELD* welder to do the job better. Each has superior features that distinguish it from other makes . . . features you'll like, features your operators will like. Check the design, the construction, the performance, the easy operation, the power consumption. Get the facts today. Your NCG dealer or nearest NCG office is ready to serve you.

**When you work with metals . . . work with**

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No matter what the job . . . in cutting, welding, brazing, or metal conditioning . . . NCG has the equipment, the experience and the organization to serve you better.

**NATIONAL CYLINDER GAS COMPANY**
**840 North Michigan Avenue, Chicago 11, Illinois**
***Branches and dealers from coast to coast***
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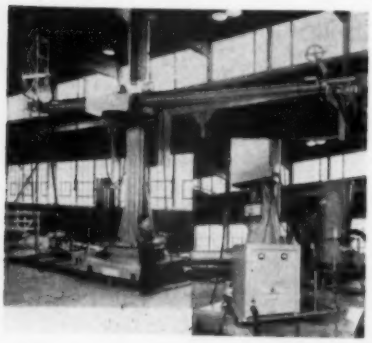
**ELECTRODES AND GAS RODS ★ ARC-WELDERS ★ CUTTING MACHINES ★ HIGH PURITY GASES**
**CUTTING AND WELDING TORCHES ★ WELDING AND CUTTING ACCESSORIES**

Additional information may be obtained from the manufacturer at the above address.

## Positioned Welding

A new heavy-duty ram-type manipulator for automatic welding recently completed for a large West Coast fabricator is pictured under test at the plant of C. B. Herrick Manufacturing Corp., Cleveland.



Of welded construction throughout, the unit has a motorized vertical-adjustment range of from 3 to 18 ft, with variable-speed ram travel of 20 ft, and 360° rotation on the carriage. The welding head will enter a 24-in. diam cylinder.

Power supply for welding will be provided by a Model 200065 Controlled Arc Power Supply furnished by Metal & Thermit Corp.

For further information, write to Metal & Thermit Corp., 100 Park Ave., New York 17, N. Y.

## Plastic Safety Hat

According to the manufacturer, the "Life Guard" all-plastic safety hat for electrical workers surpasses all Edison Institute requirements. It resists well over 20,000 volts. By also passing Federal Specification tests for construction workers' hats, it offers superior safety margins to workers in both trades.

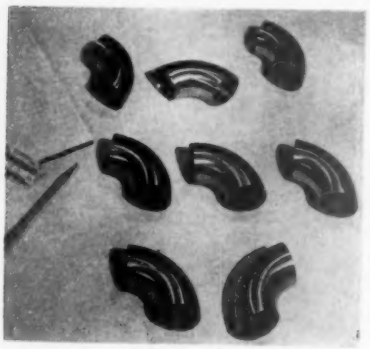
The comfortable headgear has strength and flexibility to cushion impact, and a soft sweatband all around. The headband instantly adjusts to marked hat sizes $6^1/_2$ through $7^3/_4$.

A hat and cap are offered, both in white, yellow and grey. Non-metallic chin straps and winter liners are available.

For further information, write to Jackson Products (Air Reduction Sales Co., a division of Air Reduction Co., Inc.), 31739 Mound Road, Warren, Mich.

## Zirconium Fittings

What are believed to be the first welding fittings of zirconium and Zircaloy 2 have been forged by Tube Turns, Louisville, Ky., a division of National Cylinder Gas Co. They were designed for a nuclear energy application.



The fittings have an outside diameter of 1.5 in. and a 0.065-in. wall.

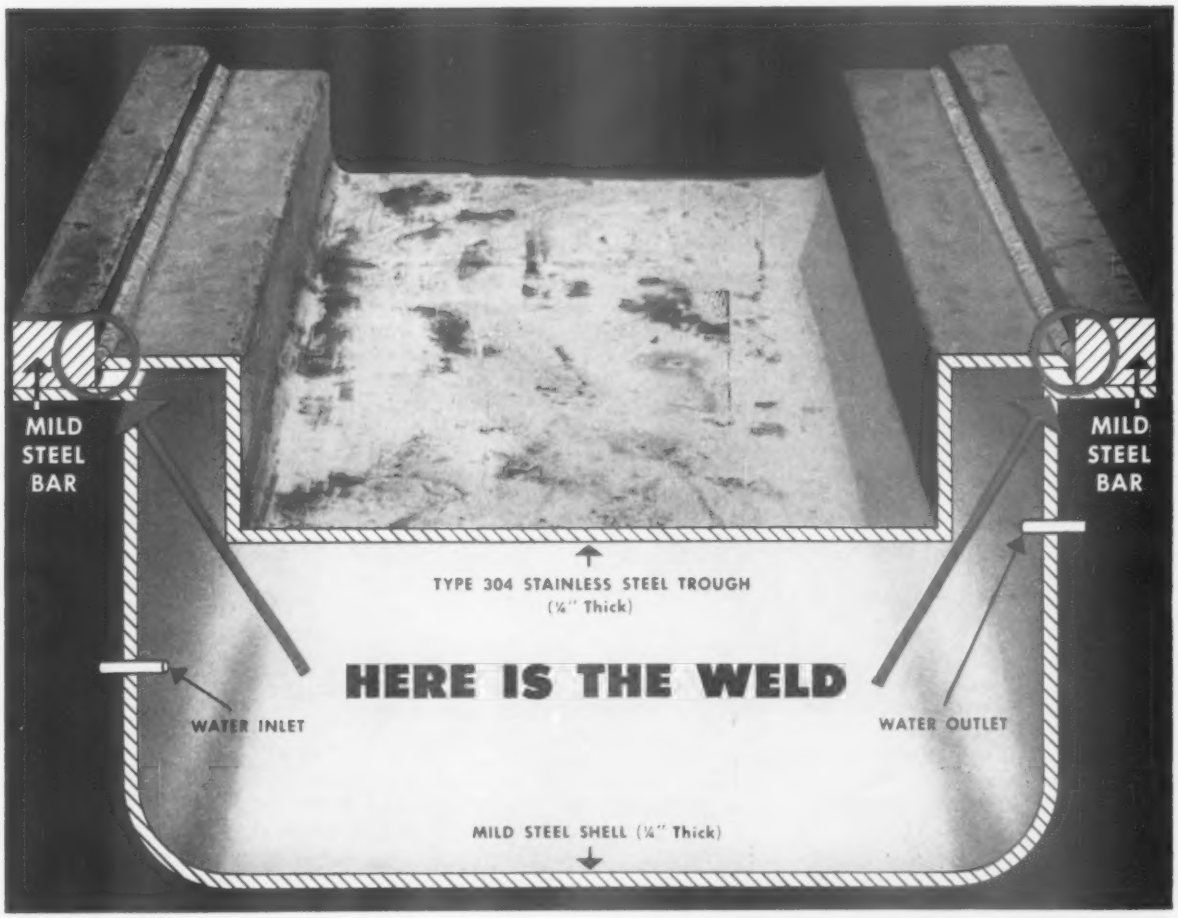
According to the manufacturer, laboratory tests and field experience show that these materials have a combination of desirable properties, and that they can effect important economies when properly applied. In addition to providing excellent resistance against the attack of a wide variety of corrodents they have a very low thermal cross section (0.18 Barns), and possess relatively good strength up to moderately high temperatures.

For additional information, write to Tube Turns, 224 E. Broadway, Louisville 1, Ky.

## Coating Compound

Glyptal coating compound in 16-oz pressure packs, sufficient to give corrosion protection to more than 85 sq ft of surface, is being marketed by the General Electric Co.'s Welding Department.

Pressure pack application is faster than by brush painting and is more




*No special equipment . . . No special training for the weldor*

# Inco-Rod "A" joins dissimilar alloys with strong, sound welds

Here's another example of how Inco-Rod "A"* electrode turns difficult dissimilar alloy welds into routine jobs.

A new drag conveyor at International Minerals and Chemical Corporation's Carlsbad plant consists of a 304 stainless steel trough and an outer mild steel shell. Each of its eight 5-foot sections was fabricated by welding trough and shell to mild steel bar. For the critical weld between the stainless and the mild steel, Inco-Rod "A" electrode was used.

Only standard equipment was required, and no new welding techniques had to be learned. Inco-Rod "A" electrode handled easily and produced strong, sound, crack-free joints.

Two alternatives to using Inco-Rod "A" electrode were considered and both rejected as they would be likely to produce crack sensitive welds.

**Joint trouble with dissimilar alloys?** Then why not try Inco-Rod "A" – the electrode with the green flux coating. Whether you weld ferritic or austenitic stainless steels, low alloy or mild steels, high nickel, copper nickel or other alloys, you'll find that Inco-Rod "A" electrode gives strong, ductile welds . . . of X-ray quality. What's more, the corrosion resistance of the weld deposit in most cases will be equivalent to or better than either of the alloys being welded.

Easily-handled Inco-Rod "A" electrode can be used in all positions . . . gives a spray-type arc and easy slag removal.

**More facts and figures** on using Inco-Rod "A" electrode in dissimilar alloy welding are given in Inco's new folder "*Inco-Rod 'A' Electrode.*" For your copy, write:

* Trademark of The International Nickel Company, Inc.

**THE INTERNATIONAL NICKEL COMPANY, INC.**
67 Wall Street New York 5, N. Y.

**INCO-ROD "A" electrode** is supplied in four diameters: 3/32-, 1/8-, 5/32-, and 3/16-inch . . . packed in 5-lb. containers.

INCO **Welding Products**
electrodes, wires, fluxes

economical, since it produces a narrow spray pattern ideal for a welded joint, according to company engineers. The thin coating dries more rapidly and is easy to apply in corners and difficult angles.

The Glyptal coating compound is a clear synthetic varnish. Primary applications of Glyptal coating compound: protection against corrosion and oxidation of metal pieces being stored before finish painting; anti-spatter compound; primer for finish paint on metal surfaces.

The coating compound does not have to be removed before welding. Because of its properties, spatter cannot stick or weld to a surface with this coating. After welding, the burned area can be recovered very quickly by pressure pack application.

Additional details can be obtained by writing to General Electric, Schenectady 5, N. Y.

## Magnaflux Powder Blower

A portable unit is now available for the proper application of dry Magnaflux powder. The No. 58600 Powder Blower operates directly from any air line and requires only 20 psi. A simple adjustment controls the density of the

cloud of powder, and two push buttons permit selection of either powder or clean air. By holding the gun level and at a distance from the area being tested, the particles flood the area, showing indications when cracks are present.

According to the manufacturer, this blower is compact and weighs $2^1/_4$ lb when empty. It is simple to operate and has advantages over the shaker-type powder bulbs in that it is faster, covers a wider area and distributes the magnetic particles evenly.

For further information on the No. 58600 Powder Blower, write Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill.

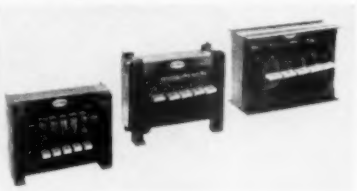
## New Regulator Series

A new series of regulators for various compressed gases is undergoing final testing at K-G Equipment Co., Allentown, Pa.

According to the manufacturer, these regulators have been developed by the Company's engineering department to combine economy and simplicity with rugged performance characteristics. They are designed for medium to light industrial applications and to meet the full requirements for all compressed gas control applications in the home hobbyist, automotive, farm and repair shop fields. The series is slated for release in August.

## Welding Transformers

Three new transformers have been added to the line of precision welding equipment made by Raytheon Manufacturing Co., Commercial Equipment Division, Waltham, Mass. Rated at $1^1/_2$, 3 and 5 kva, the transformers are



specifically designed and built for use with Raytheon Thyratron Contactors. The new transformers increase welding rates and assure more uniformity in production, according to the manufacturer. Design features include oversize cores for maximum heat dissipation; and careful distribution of copper between primary and secondary to minimize losses.

When combined with a Thyratron contactor and a Raytheon welding control a high-performance, high-speed production a-c system for welding such components as vacuum tubes, relays, precision instruments, contacts, etc., is set up.

## C-Clamp

The latest development in the Grand Clampmaster C-Clamp is a ratchet screw that instantly positions clamp

screw and releases it with a trigger action. Cuts job time by eliminating tedious turning. Alloy steel construction gives added strength and permits a throat depth up to 6 in. Screw, handle and swivel are copper plated for protection against welding spatter and rustproofed with baked enamel finish.

For further information write Grand Specialties Co., 3101 W. Grand Ave., Chicago 22, Ill.

## Automatic Welding

Welduction Corp. announces the availability of an automatic welding unit for both shielded-inert-gas metallic arc and tungsten-arc welding and also submerged-arc welding.

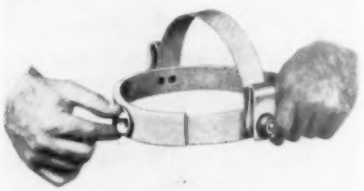
According to the manufacturer, the

unit features a radial arm to increase machine productivity through the use of multiple-station, precision positioners. The complete unit contains carriage and column 16 ft high; heavy-duty automatic precision positioners; single central-control console, including plumbing panel for air, gas and water control; and shielded-inert-gas welding heads. The manufacturer can supply all, or any portion, of these components.

For more information, write to the company c/o 10230 Capital Ave., Detroit 37, Mich.

## Headgear for Helmets

Chicago Eye Shield Co. announces a new CESCO Gl-R Headgear for helmets and face shields. This is a tough plastic headgear which permits easy and com-

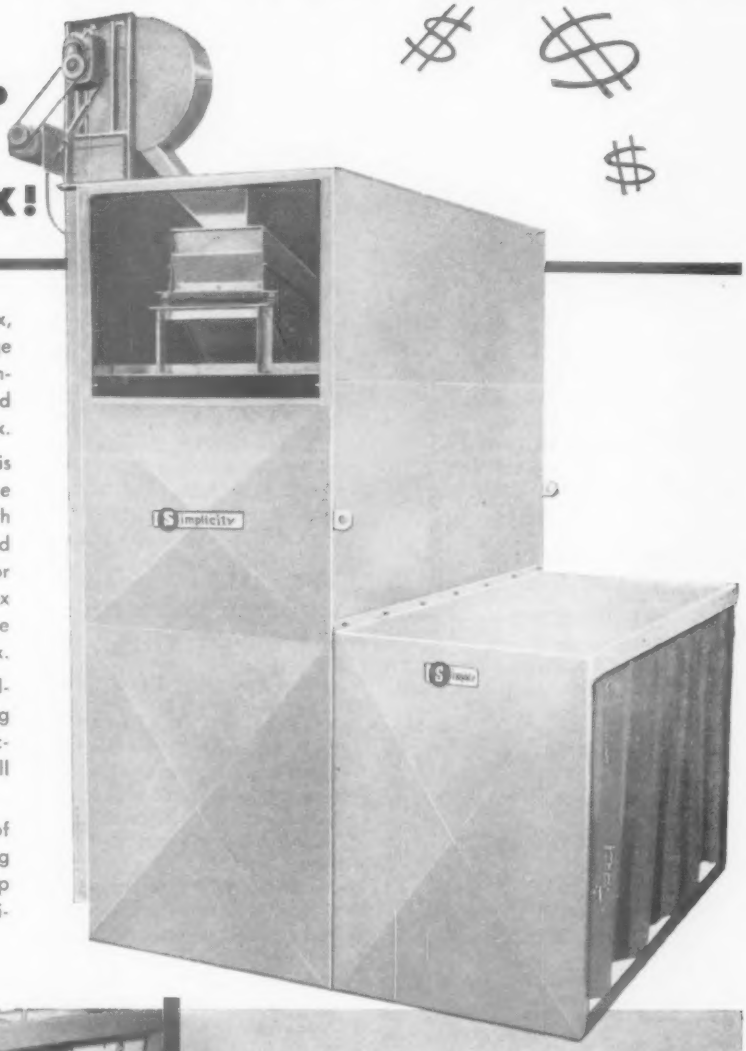


fortable fitting, according to manufacturer. It adjusts to the required head size by a mere turn or two of the adjusting ratchet.

The new headgear is now available on all CESCO welding helmets and face shields.

# THROWING MONEY AWAY?

## YOU ARE, IF YOU SCRAP SPILLED AND FUSED FLUX!

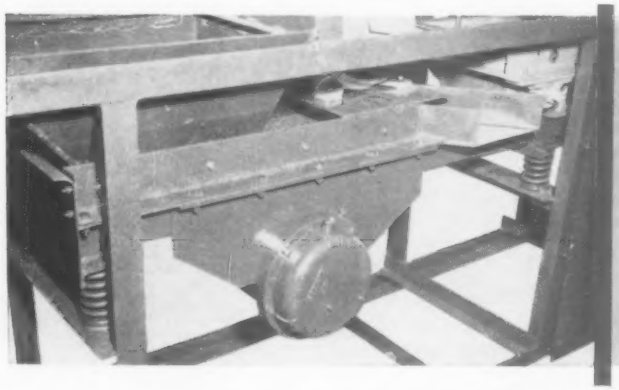


When you discard spilled and fused flux, you're throwing profits to the wind. A large automotive plant solved this problem by installing the Simplicity Flux Reclaim Unit, and saving $5,000 a month salvaging used flux.

Sound good? It should, if your plant is equipped with submerged arc welders. The Simplicity Flux Reclaimer is designed to crush used flux, remove metal particles, dust and fines, and give you refined flux ready for re-use. Mixed in proper ratio with new flux (depending upon type of work) welds are obtained equal to those made with new flux.

Equipped with a two surface vibrating feeder, bucket elevator, double deck vibrating screen, 15" x 9" crusher and two magnetic-pulleys, the Simplicity Flux Reclaimer will more than pay its own way.

Complete installation drawings and prices of these SIMPLICITY units may be had by writing directly to the factory . . . a logical first step in determining ALL the money-saving possibilities these machines may hold for you.



**View of 12" x 4'9" two surface oscillating feeder, showing side discharge for removing scrap, metal particles and other foreign objects.**

195

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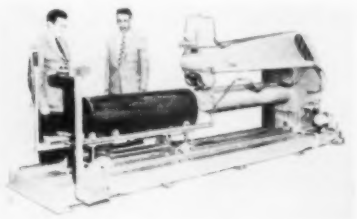
**FOR CANADA:** Simplicity Materials Handling Limited, Guelph, Ontario.
**FOR EXPORT:** Brown and Sites, 50 Church Street, New York 7, N. Y.

**Simplicity**
TRADE MARK REGISTERED

**ENGINEERING COMPANY • DURAND 23, MICHIGAN**

## Roll-Planishing Machine

A new automatic roll-planishing machine for smoothening or flattening welds is announced by Airline Welding and Engineering, 785 N. Prairie Ave.,



Hawthorne, Calif.

According to manufacturer, automatic loading and unloading features make it possible to smoothen a weld of substantial build-up in 10 sec.

For more details, write directly to company at the above address.

## Eye Drops for Eye Flash

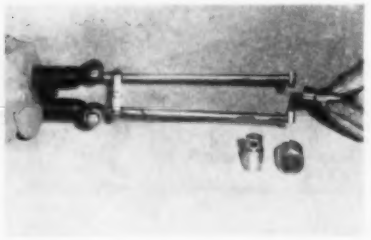
The Carhoff Co., Cleveland, Ohio, announces the availability of "Welder's Pal" eye drops for the relief of the effects of keratitis (eye irritation from exposure to arc radiation or intense light).

Liquid drops spread readily over the cornea and produce a soothing and cooling effect to inflamed or gritty eyes.

For literature and information write to Carhoff Co., 11706 Kinsman Ave., Cleveland 20, Ohio.

## Interchangeable Tips

Bethlehem Apparatus Co., Inc., Hellertown, Pa., has announced the introduction of a torch with three interchangeable tips for applications in the glass and metalworking fields. According to the manufacturer, the tip can be changed simply by squeezing the handles and forcing the tip to drop out. A new tip can then be placed between the prongs and tilted freely to any angle. The torch itself is $13\frac{1}{2}$ in. long, 10 oz in weight for the holder plus $\frac{1}{2}$ oz for the small burner head, 1 oz for the medium-sized head and $1\frac{1}{2}$ oz for the large head. For further details write to the manufacturer.



## Aluminum Welding Rod

The development of EutecRod 999FC, an aluminum alloy with an extruded coating, has been announced by the Eutectic Welding Alloy Corp., Flushing 58, New York, N. Y.

According to the manufacturer, the alloy provides for an approximate bonding temperature of 1050° F and is applicable where joint design is not critical.

For further information, write to the above address c/o Technical Information Service.

## Gas Expander Unit

The H.I.G. Corp., 7843 S. Claremont Ave., Chicago 20, Ill., announce the availability of their GasXpandr unit. This unit is intended for use in inert-gas metal-arc and tungsten-arc welding whereby the normal requirements of inert gases are reduced by the expansion of such gases in operation. The GasXpandr is a supplementary unit which can be used on manual or mechanical torches that is $1\frac{1}{2}$ x 4 in. and weighs less than 10 oz. The heating element is capable of 1200° F and is water-cooled making the outer surface safe. The heating element operates on 110 v, ac or dc. According to manufacturer, with the attachment of the GasXpandr to the welding equipment, there is no alteration whatsoever to the regular method of operation, but there is a surprising reduction of gas consumption from that normally used.

Additional information may be had by writing to H.I.G. at above address.

## Index Welding Machine

A new high-production, 5-station, rotary index welding machine that utilizes automation methods to combine assembly and $CO_2$—shielded-arc-welding operations is now available from Expert Welding Machine Co., 17144 Mt. Elliott Ave., Detroit 12, Mich.

The model illustrated press assembles and contour welds flat circular plates

to the inside of cylindrical parts at a rate of 500 finished assemblies per hour. The machine is adaptable to parts up to 5 in. in diameter that require press-type assembly and circular-weld joining.

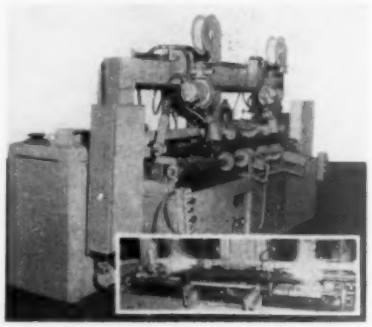
The machine consists of a cast hollow aluminum 5-station index table, two spring collet fixtures per station, an air-operated assembly press, two welding heads and a unique part unloading mechanism located inside the index table.

For complete information, write directly to the manufacturer at above address.

## $CO_2$ Automatic Welder

An automatic truck drive tube $CO_2$ welding machine of marked flexibility has been designed and built by Dix Engineering Co., Inc., (Detroit) Lincoln Park, Mich.

The new machine was custom made for a leading motor truck manufacturer. Its design met the customer's problem of speeding the welding operations on the drive shafts for their trucks.



In the course of the machine's operation the universal joint assembly is welded to the drive tube at one end with a continuous weld bead around the diameter. At the same time the driving splined shaft is welded into the drive tube at the other end.

For complete details, write directly to Dix Engineering Co. Inc., Lincoln Park, Michigan.

HAYNES Alloys solve the *tough* wear problems

# NO MAINTENANCE FOR 2 YEARS

## Trouble-free mining operation in abrasive muck with HAYNES Alloy

Ordinary bearings and rollers couldn't take this punishment and lasted about 3 weeks. But when these rollers were built-up and hard-faced with HAYNES STELLITE alloy No. 6, service life was extended to years instead of weeks!

Whether your equipment handles rock, sludge, or acid – where there's a serious wear or corrosion problem, you will find that a HAYNES alloy will reduce maintenance and replacement costs. For complete information about hard-facing, write for the Hard-Facing Manual. Address HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, Kokomo, Indiana.

**Constantly and completely covered with abrasive muck.** This equipment, deep in the mine, gathers and transports ore at the digging sites. Parts were hard-faced right on the job – almost 600 ft. below the earth's surface – with HAYNES STELLITE alloy No. 6 rod.

HAYNES ALLOYS

HAYNES STELLITE COMPANY

*Division of Union Carbide Corporation*

Kokomo, Indiana

UNION CARBIDE

"Haynes," "Haynes Stellite" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

## Soldering Equipment

An automatic soldering machine has been developed by Castle Machines, Inc., of Erie, Pa. The basic machine is said to be a new concept in feeding solder automatically through magazines to preheated parts for solder fabrication.

The timing mechanism operates and regulates the flame and the exact amount of solder in connection with an index table. It localizes the heat at the point of fabrication in the same manner as it would be done manually, thereby, accomplishing high quality soldering at a greatly increased production rate.

The newly developed equipment is reported to work equally well with all known forms of soldering and all types of metals. The equipment is designed for one operator, and has been named Braze-O-Matic.

For complete details write to manufacturer at above address. Department W.J.

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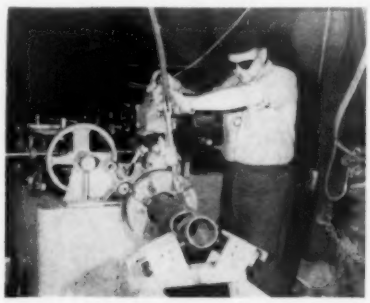
## Pipe-Cutting Machine

The "Mechanical Draftsman," developed by Steffan Engineering, Salem, Ohio, is an oxygen-flame pipe-cutting machine which automatically generates, cuts, bevels and properly contours pipe joints for any given angle of intersection without cams, patterns or



templates—and with mathematical precision—according to its manufacturer.

The "Mechanical Draftsman" is said to require only that three simple settings be made by the operator—on easily adjusted scales—to conform to the ID of the pipe being cut, the OD of the pipe being intersected, and the angle of intersection.

Two models handle pipe diameters up to 24 in. in any wall thickness. Complete details may be had by writing to Steffan Engineering at above address.

## Hard-Surfacing Machine

A fully automatic machine for hard surfacing disks, plow shares, grader blades and similar thin-sectioned parts is now in production by L and B Welding Equipment, Inc., of Berkeley, Calif.

Designated the "Optiflame" Model D, the machine uses a light-temperature response system for automatically controlled preheat, weld heat and postheat. Hard-surfacing wire is fed with positive pressure against the workpiece through an oscillating feeder which "wipes" the rod against the work to break up scale and oxides, and to keep the puddle clean. Its action assures uniformly top-quality deposits of all

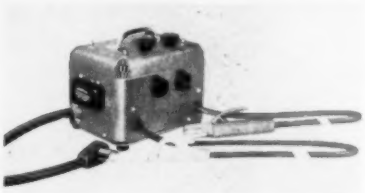
popular alloys, including tungsten carbides. Stick electrodes may also be used.

Literature and complete data can be obtained from Stoody distributors, or from the manufacturer—L & B Welding Equipment, Inc., 2424 Sixth St., Berkeley 2, Calif.

## Arc Welders

Power Arc Corp., Peoria, Ill., has introduced a line of small, compact, portable welders intended for general maintenance and repair work.

The model 200A delivers 200 amp on 230 volt lines and 180 amp on 115 or 208 volt lines. Weighing just 65 lb, it



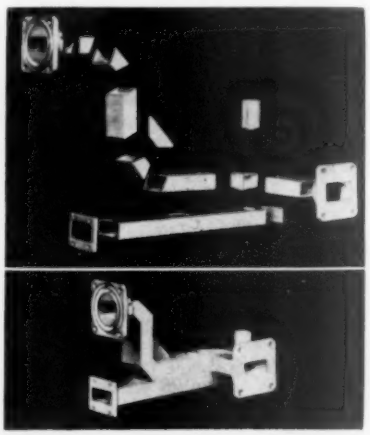
has a maximum 25-volt output which permits contact or arc welding, giving excellent penetration.

A larger machine, the model 400A, works on 440 or 230 volt lines.

Additional information can be obtained by writing Power Arc Corp., 3516 N. Adams Street, Peoria, Ill.

## Flux Dip Brazing

Flux dip brazing, a new technique for joining complex, multijoint aluminum assemblies in one operation, is now available through Waveline, Inc., of Caldwell, N. J., according to an announcement by the manufacturer. This process eliminates the many draw-



backs of hand brazing and assures high-volume, low-cost production. Flux dip brazing can be used for brazing waveguides, antennas, chassis and microwave assemblies. Additional information may be obtained by writing to Waveline, Inc., Caldwell, N. J.

# This Amazing New Limit Switch Operates Without Physical Contact!

Transducer (sensing head) is actuated by presence of magnetic materials over a wide range of sizes, shapes, weights, roughness, speeds

No moving parts. No metal-to-metal contact required for operation

Sensitivity up to 1 inch

Can be mounted in any position. Not affected by vibration

Small size (1⅞" x 6") Fits into tight spots

Non-magnetic material between the part and transducer does not affect operation

• Here's an entirely new concept in industrial limit switches! We've named it the **PROXIMITY LIMIT SWITCH** because it is actuated by the nearness of ferrous parts or materials. Since its operation requires no physical contact, it has unlimited applications in places where the use of conventional limit switches is either impractical or impossible! Its range of application is broadened, too, because the transducer (sensing head) is not affected by vibration or by the presence of non-magnetic material.

In paint spray systems, on production line presses, multiple process machines, heavy automation equipment—there are literally scores of places where this amazing new PROXIMITY SWITCH will do the job better!

**ASK YOUR SQUARE D FIELD ENGINEER FOR A DEMONSTRATION. OR WRITE FOR PROXIMITY LIMIT SWITCH BULLETIN. ADDRESS SQUARE D COMPANY, 4041 NORTH RICHARDS STREET, MILWAUKEE 12, WISCONSIN**

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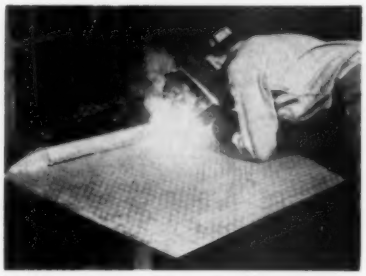
## Inert-Arc Welding of Magnesium

The Lite-Line Metal Industries Division of Copperloy Corp., Cleveland, Ohio, has announced a welding method which reportedly permits automatic, continuous welding of magnesium, using the shielded-inert-arc, consumable-electrode process. This process employs a small diameter coiled wire as both filler metal and electrode.



The manufacturer states the frequency of "burn-back" has resulted in the development of a device, patented by Lite-Line, which permits continuous welds up to 30 ft in length on magnesium. This method increases the speed of magnesium welding by four to six times over the conventional, manual method.

For more information, write to the manufacturer at 4103 Brookpark Road, Cleveland 29, Ohio.

## Spot-Welding Gun

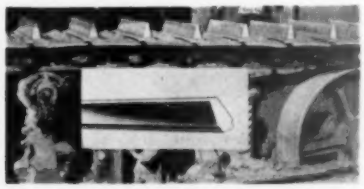
The Tec Torch Co., Inc., 300 Paterson Ave., Carlstadt, N. J., announces the development of their "Tec Spot Gun," a feature of which is its utilization of the tungsten-arc inert-gas welding process with high-frequency initiation.

The manufacturer states that in addition to being used with power sources having built-in "spot-gun" controls, the "Tec Spot Gun" introduces the use of a second welding timer, selection of which is built into the gun itself. This additional timer gives the operator a selection of weld-depth penetration of any two joint applications in one production line without returning to the power source for readjustments.

For more information, write to the manufacturer at the above address.

## Tractor-Grouser Retreads

A new line of tractor-grouser retreads for rebuilding the grouser shoes of track-laying or crawler-type equipment has been announced by Allied Steel & Tractor Products, Inc., 7835 Broadway, Cleveland 5, Ohio.

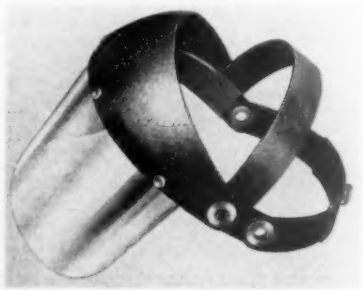


According to the manufacturer, Bulldog Tractor Grip-Lugs have a specially-designed shape, with an engineered groove and bevel, that permits welding application much faster and cheaper than using original parts. Inexpensive AWS E6016 or E7016 low-hydrogen electrodes can be used.

More information may be obtained by writing the manufacturer at the above address.

## Synthetic Shields

American Optical Co. announces a new aluminized-plastic cover plate for welding helmets, and a new aluminized-cellulose-acetate face-shield window, for protection against radiant heat. According to the manufacturer, windows enable workers to work longer and with greater efficiency on furnace operations, melting, forging and metal pouring. Plates are exceptional for inert-gas shielded arc welding. Both are treated with an evaporated aluminized coating, which reflects more than 70% of radiant heat normally reaching the worker's face.



For full information, write for Brochure S-6310, American Optical Co., Safety Products Division, Southbridge, Mass.

# HARRIS propane cutting unit

## *OFFERS GREATER DIVIDENDS*

### THE torch designed specifically for **LP GAS**

Harris model 62-2F torches have a specially designed mixer which ensures complete mixture of the propane and oxygen. Tips are designed especially for propane. This combination results in faster preheating; eliminates wasting oxygen.

Harris "L" type regulators permit setting the pressures as required for maximum economy and safety, with removable adjusting keys.

### ✳ CHECK THESE OUTSTANDING FEATURES!

- Fuel cost reduced up to 90%
- Faster, easier cutting on rusty or scaly surface
- Withstands abuse in tough cutting operations
- "Automatic" flame adjustment
- Outstanding ability to preheat quickly
- Longer tip life

### COMPLETE PROPANE CUTTING UNIT, 62-2F/L-92

**62-2F 90° (or 62-2AF 70° head)** cutting torch
**LX-92-SC** lock type oxygen regulator
**L-92-SC-P** lock type propane regulator
**6290-NFF** extra fast preheat cutting tips available in sizes from **000-NFF to 6-NFF**

Similar equipment available for natural gas. Information on request.

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**FOR ALL HEAT-DEPENDENT OPERATIONS**

*looks like a crayon... marks like a crayon... tells temperatures like a precision instrument!*

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TEMPILSTIK° marks on workpiece "say when" by melting at stated temperatures — plus or minus 1%.

ALSO AVAILABLE IN LIQUID AND PELLET FORM . . . WRITE "WELDING SALES" DEPT. FOR SAMPLE TEMPIL° PELLETS . . . STATE TEMPERATURES OF INTEREST—PLEASE!

**Available in these Temperatures (F.)**

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|---|---|---|
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| 125 | 388 | 1050 |
| 138 | 400 | 1100 |
| 150 | 413 | 1150 |
| 163 | 425 | 1200 |
| 175 | 438 | 1250 |
| 188 | 450 | 1300 |
| 200 | 463 | 1350 |
| 213 | 475 | 1400 |
| 225 | 488 | 1450 |
| 238 | 500 | 1500 |
| 250 | 550 | 1550 |
| 263 | 600 | 1600 |
| 275 | 650 | 1650 |
| 288 | 700 | 1700 |
| 300 | 750 | 1750 |
| 313 | 800 | 1800 |
| 325 | 850 | 1850 |
| 338 | 900 | 1900 |
| 350 | 950 | 1950 |
| 363 | | 2000 |

**Tempil° CORPORATION** 132 WEST 22ND STREET, NEW YORK 11, N. Y.


## INDEX TO ADVERTISERS


Air Reduction ..... Outside back cover
Alloy Rods Company ..... 833
All-State Welding Alloys Co., Inc. ..... 834
The American Brass Company ..... Inside back cover
Anti-Borax Compound Co. ..... 840
Aronson Machine Company ..... 825
C. F. Braun & Co. ..... 840
Cam-Lok Div., Empire Products, Inc. ..... 817
Convair ..... 840
Drawalloy Corporation ..... 835
Eutectic Welding Alloys Corp. ..... 837
Harris Calorific Company ..... 859
Haynes Stellite Company, A Division of Union Carbide Corp. ..... 855
Hobart Bros. Co. ..... 765
The International Nickel Co., Inc. ..... 770, 851
The Lincoln Electric Company ..... 839
Linde Company, A Division of Union Carbide Corporation ..... 768
P. R. Mallory & Co., Inc. ..... 767
Metal & Thermit Corporation ..... 845
Miller Electric Manufacturing Co., Inc. ..... 772
National Carbide Company ..... 832
National Cylinder Gas Company ..... 848, 849
National—U. S. Radiator Corporation ..... 831
National Welding Equipment Co. ..... 766
Republic Aviation ..... 840
Robotron Corporation ..... 841
Simplicity Engineering Company ..... 853
Square D Company ..... 857
Stulz-Sickles Co. ..... 850
Tempil° Corporation ..... 860
Tube Turns, Inc. ..... 861, 862
Union Carbide Corporation
Haynes Stellite Company ..... 855
Linde Company ..... 768
Victor Equipment Company ..... Inside front cover
Westinghouse Electric Corp. ..... 844

*View between the two 2250-ton compressors at Garden State Plaza.*

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*Piping that helps*

# AIR CONDITIONING PAY OFF

● Air conditioning has become a giant industry because it provides valuable *user benefits*...more customers, increased working efficiency, greater profit.

Tube Turns is proud to be associated with this growing business, giving it assistance in piping engineering and supplying the top-quality, welded-piping fittings essential for dependable air conditioning systems.

More than 12,000 TUBE-TURN* products are available from your nearby Tube Turns' Distributor for *all* your needs in welded piping of *all* kinds.

**AIR CONDITIONED.** Buildings alone for the new Garden State Plaza Shopping Center at Paramus, N. J., cover 10 acres. Two 2250-ton compressors provide for the air conditioning system. All welded piping with TUBE-TURN fittings ranges from ½" to 18" diameter. Architect-Engineer: Abbott, Merkt & Co.; General Contractor: Joseph L. Muscarelle; Mechanical Contractor: Frank A. McBride Co.

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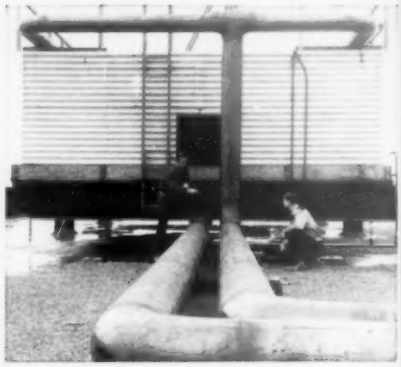

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# Welding Research

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W. SPRARAGEN, DIRECTOR

SUPPLEMENT TO THE WELDING JOURNAL AUGUST, 1957


# CORROSION RESISTANCE OF NO. 20 AND NO. 20Cb STAINLESS-STEEL WELDS

*Test program indicates that No. 20Cb weld metal is subject to less severe intergranular corrosive attack than the No. 20, particularly in the as-welded and the sensitized conditions*


BY HALLOCK C. CAMPBELL, THOMAS J. MOORE AND S. E. TYSON



**ABSTRACT.** Severe tests which were designed to investigate the comparative corrosion behavior of No. 20 and No. 20Cb welds in several conditions of heat treatment have shown that the No. 20Cb analysis is less subject to intergranular corrosive attack than the No. 20, but it is more subject to weld cracking. Both analyses become highly susceptible to intergranular corrosive attack after exposure to 1350° F for only two minutes. Annealing appears to be accomplished by heating to 1700° F for two hours, followed by a water quench.

The No. 20Cb base metal should be welded with No. 20Cb electrodes, and the No. 20 with No. 20 electrodes; however, if the vessel can be annealed either electrode may be used. When there is danger of weld cracking, No. 20 electrodes should be used, but the vessel must be heat treated to prepare it for corrosive service.


## Introduction

The wrought, super corrosion-resistant stainless steel whose welding is the subject of this report was developed in 1948. It contains nickel, chromium, copper and molybdenum and is known as stainless No. 20. Previously available only in cast form, this alloy exhibits excellent corrosion resistance, especially to hot sulfuric acid and most organic acids. It has found wide use in all phases of the chemical industry.


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Many applications such as heat exchangers and tanks require welded construction to avoid crevice corrosion. Since most fabricated equipment cannot be subsequently annealed, plate, sheet, strip, pipe and tubing are made of a columbium-stabilized variation, stainless No. 20Cb, to minimize the possibility of intergranular corrosion. This alloy is described in ASME Code Case 1188.

Electrodes for metallic-arc welding are available in both No. 20 and No. 20Cb grades. The cracking tendencies of these two compositions differ somewhat; it is generally recognized that columbium additions to austenitic-stainless-steel electrodes promote weld cracking under conditions of severe restraint, such as are encountered in the foundry industry. For casting repair work, No. 20 electrodes can be employed with no danger of sensitized weld metal if the entire weldment is properly annealed after welding. However, No. 20Cb electrodes have been used elsewhere under adverse conditions, and the industry reports of weld cracking were sufficiently annoying to prompt an investigation of weld-metal cracking tendencies.

Our crack-sensitivity tests showed that columbium additions tend to promote cracking. Accordingly, additional studies were undertaken to investigate the need for the columbium-bearing grade by means of corrosion tests.

This paper briefly reviews the crack sensitivity tests and in the body of the report covers the work our companies have performed to illustrate the comparative corrosion behavior of No. 20 and No. 20Cb welds. It was decided to emphasize the difference between the alloys by choosing severe corrodents as well as the sulfuric acid to which these materials might be exposed in service. Also several post welding heat treatments were employed in order to emphasize any difference in the corrosion resistance of these alloys.

## Weld-Cracking Investigation

For the study of cracking, a number of tests were undertaken using several electrode sizes and stainless No. 20Cb base material. The design of the circular-groove specimen used in these tests is shown in Fig. 1. Results of the cracking tests may be summarized by the typical values listed below for $^5/_{32}$-in. diam electrodes:

**Typical Results from Circular-Groove Cracking Tests**

| *Type of electrode* | *No. of tests* | *Average % Cracking Bead* | *Crater* | *Total* |
|---|---|---|---|---|
| No. 20 | 3 | 0 | 5.6 | 5.6 |
| No. 20Cb | 3 | 14 | 8.1 | 22.1 |

Since the extent of crater cracking is largely a function of the manner in

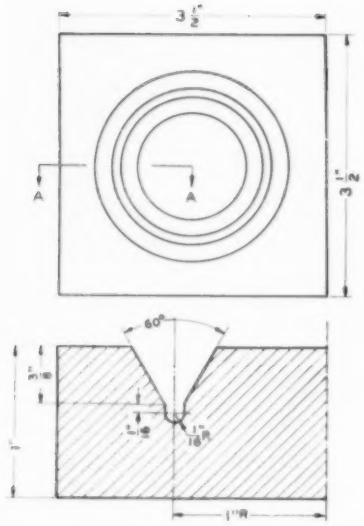



Fig. 1 Circular-groove crack-sensitivity test specimen used to compare No. 20 and No. 20Cb weld deposits

which the arc is broken, the actual numerical values of crater cracking are not overly significant, although it has been the practice to carefully measure all cracking in this test.

The greatest significance of the above data lies in the fact that no bead cracking was discovered for the No. 20 weld metal, while an average of 14% bead cracking resulted when columbium additions were made. These results indicate that columbium tends to be a crack promoter for this weld-metal composition.

## Corrosion-Test Procedures

Chemical analyses of the No. 20 and No. 20Cb undiluted weld metals were obtained using the practices recommended in the AWS-ASTM A298–55T specification. The analyses are listed in Table 1.

All-weld-metal corrosion specimens were prepared in accordance with AWS-ASTM specification A298–55T, appendix, part IV, using a Type 304L base plate. The electrodes which were employed in preparing the No. 20 and No. 20Cb weld pads were $^5/_{32}$-in. diam. A short arc was maintained during welding using 115 amp dc and reverse polarity.

The pads from which the specimens for the acidified copper-sulfate test were obtained were made $3^1/_2$-in. wide in order to have the test specimen of adequate length to allow bending the required 180° after the corrosion test.

Transverse specimens were obtained from single-V groove weldments prepared with $^1/_2$-in. thick stainless No. 20Cb plate material using the electrodes and welding conditions mentioned before. The chemical analysis of the base plate is given in Table 1.

Table 1—Chemical Analyses of Materials

| | *Undiluted weld metals* | | |
|---|---|---|---|
| | *No. 20 (9914)* | *No. 20Cb (9911)* | *$^1/_2$-in. Stainless No. 20Cb plate* |
| C | 0.04 | 0.05 | 0.06 |
| Mn | 1.45 | 1.54 | 0.87 |
| Si | 0.17 | 0.28 | 0.45 |
| S | 0.012 | 0.014 | 0.011 |
| P | 0.015 | 0.014 | 0.019 |
| Cr | 19.51 | 19.65 | 20.73 |
| Ni | 28.52 | 28.80 | 29.77 |
| Mo | 3.05 | 2.92 | 2.47 |
| Cb | ... | 0.81 | 0.83 |
| Cu | 3.09 | 3.12 | 3.06 |

All-weld-metal and transverse specimens were in the following conditions of heat treatment prior to corrosion testing: (1) as-welded, (2) 1250° F for 1 hr, air cooled (standard sensitizing treatment), (3) 1350° F for 2 min, air cooled (sensitizing treatment), (4) 1700° F for 2 hr, water quench (low-temperature anneal) and (5) 1950° F for $^1/_2$ hr, water quench (standard annealing treatment).

The heat treatment at 1350° F for 2 min was employed in this investigation on the basis of isothermal sensitization curves prepared by the steel producer for stainless No. 20 and No. 20Cb wrought materials. These data are graphically presented in Fig. 2. Note that both compositions exhibit the most marked sensitivity to intergranular attack in nitric acid after heat treatment at approximately 1350° F. Secondly, at 1350° F corrosion rates for the stainless No. 20 wrought material exceeded 24 mils per year* after exposure for approximately 45 sec. At the same temperature, slightly more than 6 min were required for the stainless No. 20Cb alloy to exhibit corrosion rates in excess of 24 mils per year.

* A penetration by the boiling nitric acid test of 24 mils per year (0.002 in. per month) is considered "acceptable" by many corrosion experts.

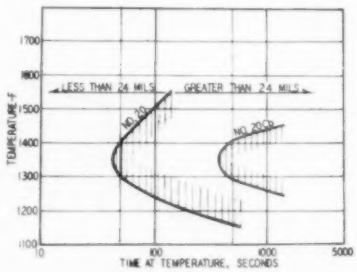



Fig. 2 Isothermal sensitization of stainless No. 20 and No. 20Cb wrought materials. Approximate boundaries of boiling nitric acid corrosion rates in excess of 24 mils per year. The materials were initially annealed at the optimum temperature for each type (2050° F for No. 20, 1950° F for No. 20Cb)

Table 2—Boiling Nitric Acid Corrosion Data on All-Weld-Metal Specimens

Corrosion Rate, Mils Penetration per Year

| *Condition* | *Avg of five 48-hr periods* *No. 20* | *No. 20Cb* |
|---|---|---|
| As-welded | 40, 40 | 12, 13 |
| 1250° F for 1 hr, air cooled | 470, 440 | 850, 900 |
| 1350° F for 2 min, air cooled | 330, 340 | 360, 580 |
| 1700° F for 2 hr, water quenched | 6, 6 | 9, 10 |
| 1950° F for $^1/_2$ hr, water quenched | 5, 5 | 8, 8 |

Table 3—Sulfuric Acid Corrosion Data on All-Weld-Metal Specimens

Corrosion Rate, Mils Penetration per Year

| *Condition* | *Avg of five 48-hr periods* *No. 20* | *No. 20Cb* |
|---|---|---|
| As-welded | 52, 51 | 58, 54 |
| 1250° F for 1 hr, air cooled | 78, 86 | 57, 62 |
| 1350° F for 2 min, air cooled | 71, 82 | 59, 45 |
| 1700° F for 2 hr, water quenched | 57, 71 | 68, 66 |
| 1950° F for $^1/_2$ hr, water quenched | 63, 55 | 48, 45 |

Table 4—Nitric-Hydrofluoric Acid Corrosion Data on All-Weld-Metal Specimens

Corrosion Rate, Mils Penetration per Year

| *Condition* | *Avg of five 2-hr periods* *No. 20* | *No. 20Cb* |
|---|---|---|
| As-welded | 2100, 2000 | 670, 540 |
| 1250° F for 1 hr, air cooled | 5400, 5800 | 3900, 3700 |
| 1350° for 2 min, air cooled | 6400, 5900 | 3200, 3100 |
| 1700° F for 2 hr, water quenched | 670, 630 | 490, 520 |
| 1950° F for $^1/_2$ hr, water quenched | 500, 440 | 390, 420 |

The 1700° F heat treatment was undertaken to see if an annealing effect would be accomplished, as suggested by the C curve shown in Fig. 2. The standard sensitizing heat treatment at 1250° F and the annealing heat treatment at 1950° F were employed to determine the difference in corrosion rates for the No. 20 and No. 20Cb weld metals in these conditions.

In each of the above conditions of heat treatment, all-weld-metal specimens in duplicate were subjected to the following corrosion tests.

1. Boiling nitric-acid test: Five 48-hr periods in boiling 65% nitric acid, in accordance with ASTM specification A262–55T.

2. Boiling 10% sulfuric acid, for five 48-hr periods.

3. 10% nitric—3% hydrofluoric acids, for five 2-hr periods at 180° F.

Additionally, all-weld-metal specimens in the as-welded and 1250° F heat-treated conditions were subjected to the following test.

4. Acidified copper-sulfate test: copper-sulfate sulfuric-acid boiling solution for one period of 72 hr, as described in ASTM specification A393–55T.

Transverse specimens in all of the conditions of heat treatment were subjected to the sulfuric acid test.

### Corrosion-Test Results

The results of the all-weld-metal corrosion tests, computed on the basis of equivalent penetration in mils per year, are presented in Tables 2, 3, and 4 for the boiling nitric, sulfuric, and nitric-hydrofluoric acid tests, respectively. A graphic presentation of these data is shown in Fig. 3.

An examination of the nitric acid results in Fig. 3 reveals that the calculated corrosion rate for the No. 20Cb weld metal in the as-welded condition is substantially lower than that for the No. 20 weld metal. Since the degree and selective nature of the attack for the No. 20 weld were much more severe than they were for the No. 20Cb, the slightly higher calculated rates for the latter, in the other conditions of heat treatment, are not felt to be significant. This point will be brought out more clearly later in this report.

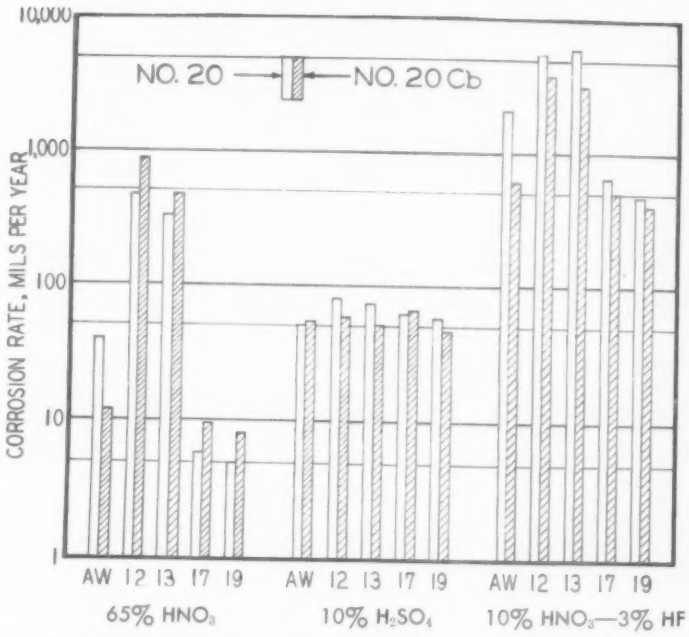


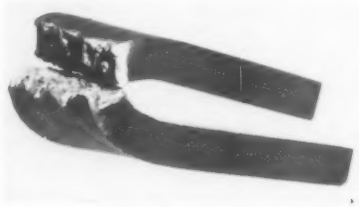

Fig. 3 The effect of heat treatment on the comparative corrosion resistance of No. 20 and No. 20Cb weld metals in several types of corrosive media.

AW—As-Welded
12—1250° F, 1 hr, air cooled
13—1350° F, 2 min, air cooled
17—1700° F, 2 hr, water quenched
19—1950° F, 1/2 hr, water quenched

The sulfuric acid calculated corrosion rates as viewed in Fig. 3 seem to be little affected by heat treatment, i.e., the as-welded corrosion rate for both No. 20 and No. 20Cb welds is not affected in a major way by any of the heat treatments. The attack on both compositions was intergranular in nature, but more severe for the No. 20 weld.

The nitric-hydrofluoric acid test results indicate that the No. 20Cb weld metal is more resistant to attack in this severe corrodent than the No. 20 weld metal, especially in the as-welded condition.

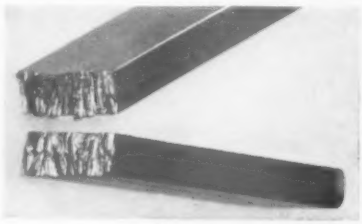
In Fig. 4, all-weld-metal acidified copper sulfate specimens in the as-welded condition are shown after corrosion testing and subsequent bending. It should be noted that the No. 20Cb weld metal passed this test while the No. 20 weld metal failed. The effect of a 1250° F sensitizing heat treatment is shown in Fig. 5. Both compositions failed this test; however, the No. 20Cb specimen could be bent 180 deg without complete failure (even though many tears were present) while the No. 20



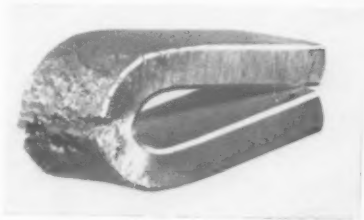
No. 20

No. 20Cb

Fig. 4 All-weld-metal acidified copper sulfate specimens in the as-welded condition after testing and subsequent bending. Enlarged approximately X 1 1/2.



No. 20



No. 20Cb

Fig. 5 All-weld-metal acidified copper sulfate specimens in the sensitized (1250° F for 1 hr, air cooled) condition after testing and subsequent bending. Enlarged approximately X 1 1/2.

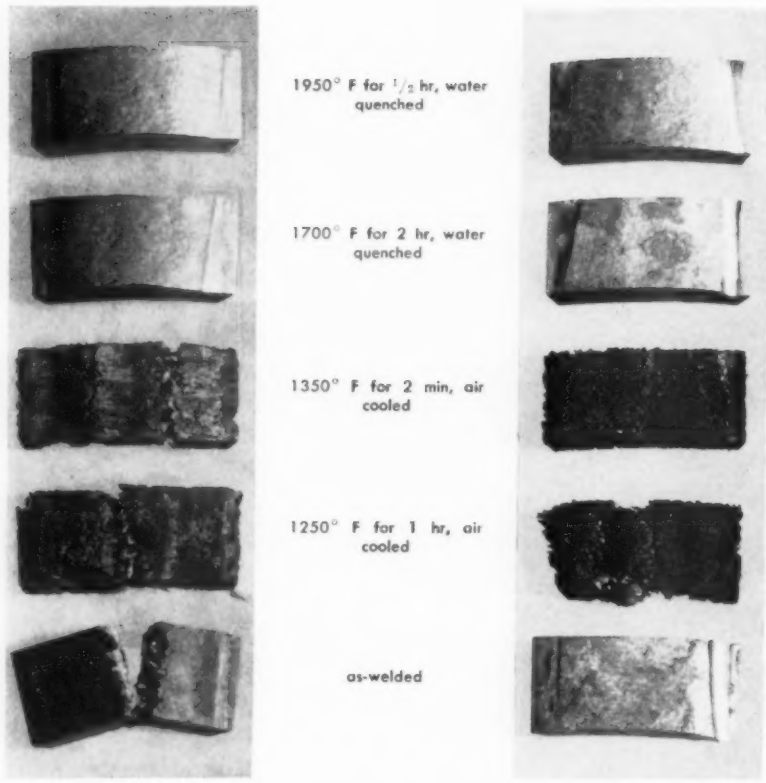

1950° F for 1/2 hr, water quenched
1700° F for 2 hr, water quenched
1350° F for 2 min, air cooled
1250° F for 1 hr, air cooled
as-welded
No. 20
No. 20Cb

Fig. 6 Tested and bent all-weld-metal nitric acid corrosion specimens in various conditions of heat treatment. The indentations near the ends of the specimens were made by the vise during the bending operation. Enlarged approximately X 1 1/8.

specimen failed at a very small angle of bending.

An uncorroded No. 20 specimen which had been given the 1250° F sensitizing heat treatment bent 180 deg without sign of fissuring, showing that it is the intergranular attack by the solution and not the heat treatment which results in the complete loss of bend ductility.

Although it is not the usual practice to bend the boiling nitric acid specimens after testing, this was found to be a more effective and striking manner in which to illustrate the difference in degree of intergranular attack between the No. 20 and No. 20Cb welds. Photographs of tested and bent nitric, sulfuric, and nitric-hydrofluoric acid specimens are shown in Figs. 6, 7 and 8 respectively.

The diagnostic value of the testing and subsequent bending technique is well illustrated in Fig. 6. Perhaps the most striking illustration is afforded by the as-welded specimens. Note that the No. 20 specimen failed completely while the No. 20Cb weld metal showed no evidence of fissuring. As may be seen in Table 2, the rate of attack for the No. 20Cb weld was 12 mils per year while that for the No. 20 was 40 mils per year. This difference is, perhaps, significant, but the innate nature of the attack could not be fully appreciated without the bend test. This point is further emphasized in the photographs of the other nitric acid specimens in Fig. 6. These photographs show that although the weight loss may be slightly higher for the No. 20Cb weld metal, the intergranular attack is less severe.

The above discussion applies also to the bent specimens which were first tested in sulfuric acid (Fig. 7). The photographs of these specimens further illustrate the more severe nature of intergranular attack in the No. 20 weld metal.

All-weld-metal corrosion specimens which were bent after nitric-hydrofluoric acid testing are shown in Fig. 8. The attack appears to be rather severe, especially in the sensitized specimens. The difference in degree of attack for this set of specimens is most pronounced in the as-welded condition.

A photograph of the transverse specimens which were tested in a 10% sulfuric acid solution and subsequently bent in a vise is shown in Fig. 9. Note the rather severe attack in the No. 20 weld which was heat treated at 1350° F for 2 min.

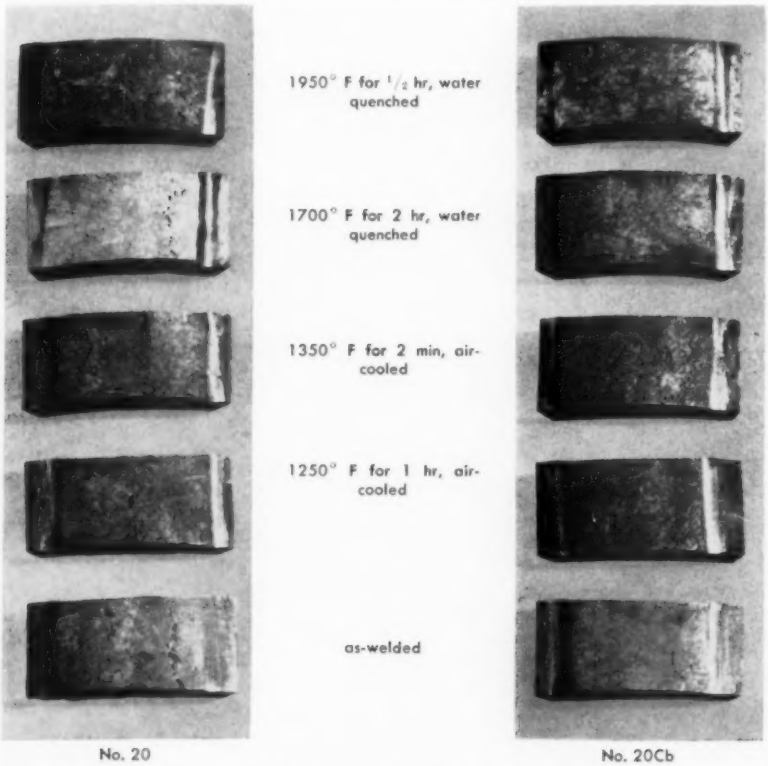

1950° F for 1/2 hr, water quenched
1700° F for 2 hr, water quenched
1350° F for 2 min, air-cooled
1250° F for 1 hr, air-cooled
as-welded
No. 20
No. 20Cb

Fig. 7 Tested and bent all-weld-metal sulfuric acid corrosion specimens in various conditions of heat treatment. Enlarged approximately X 1 1/8

### Metallographic Examination

Photomicrographs of No. 20 and No. 20Cb weld deposits in the as-welded condition are shown in Fig. 10. The grain boundary precipitation, believed to be principally chromium carbide, seems to be heavier and more continuous for the No. 20 weld metal. More matrix precipitation is evident in the No. 20Cb weld metal.

After a sensitization heat treatment of 1350° F for two minutes (Fig. 11) the grain boundary precipitation for the No. 20 weld metal appears to be more continuous than it was in the as-welded condition. The microstructure of the No. 20Cb weld metal has not been perceptibly changed.

The effect of an annealing heat treatment (1950° F for $^1/_2$ hr) is shown in Fig. 12. For the No. 20 weld metal the microstructure is essentially fully austenitic. The microstructure of the No. 20Cb weld metal is composed of columbium carbides in an austenitic matrix.

The type of attack observed in both the No. 20 and No. 20Cb weld metals was intergranular in nature for all of the corrodents. Surface attack on a No. 20Cb specimen which was sensitized at 1250° F for one hour prior to sulfuric acid testing is illustrated in Fig. 13. The corrodent is seen to be attacking the weld metal selectively at the grain boundaries. An illustration of the selective intergranular nature of the corrosive attack is presented in Fig. 14 for a No. 20 specimen which was sub-

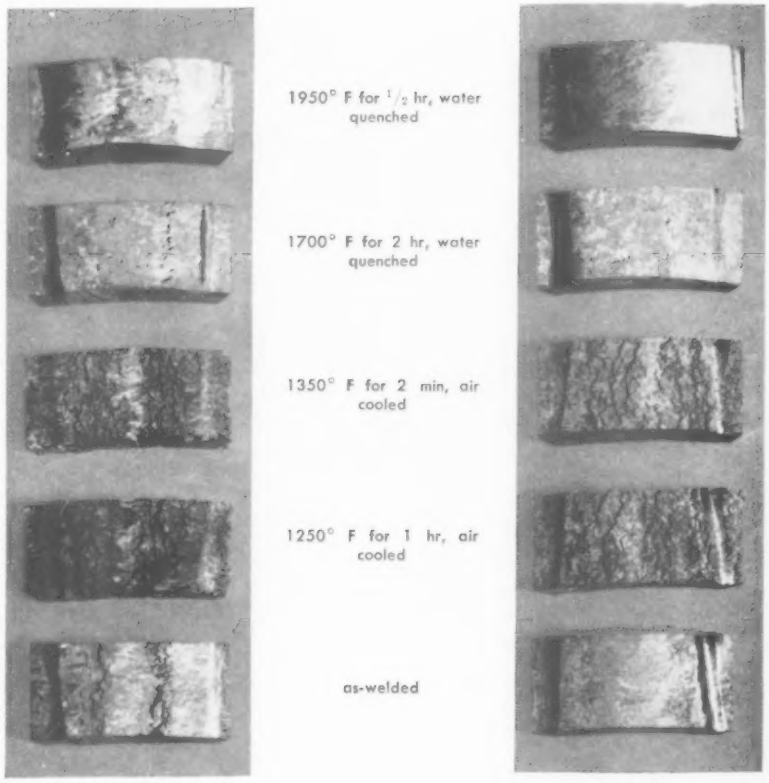

1950° F for $^1/_2$ hr, water quenched
1700° F for 2 hr, water quenched
1350° F for 2 min, air cooled
1250° F for 1 hr, air cooled
as-welded
No. 20
No. 20Cb

Fig. 8 Tested and bent all-weld-metal nitric-hydrofluoric acid corrosion specimens in various conditions of heat treatment. Enlarged approximately X $1^1/_8$

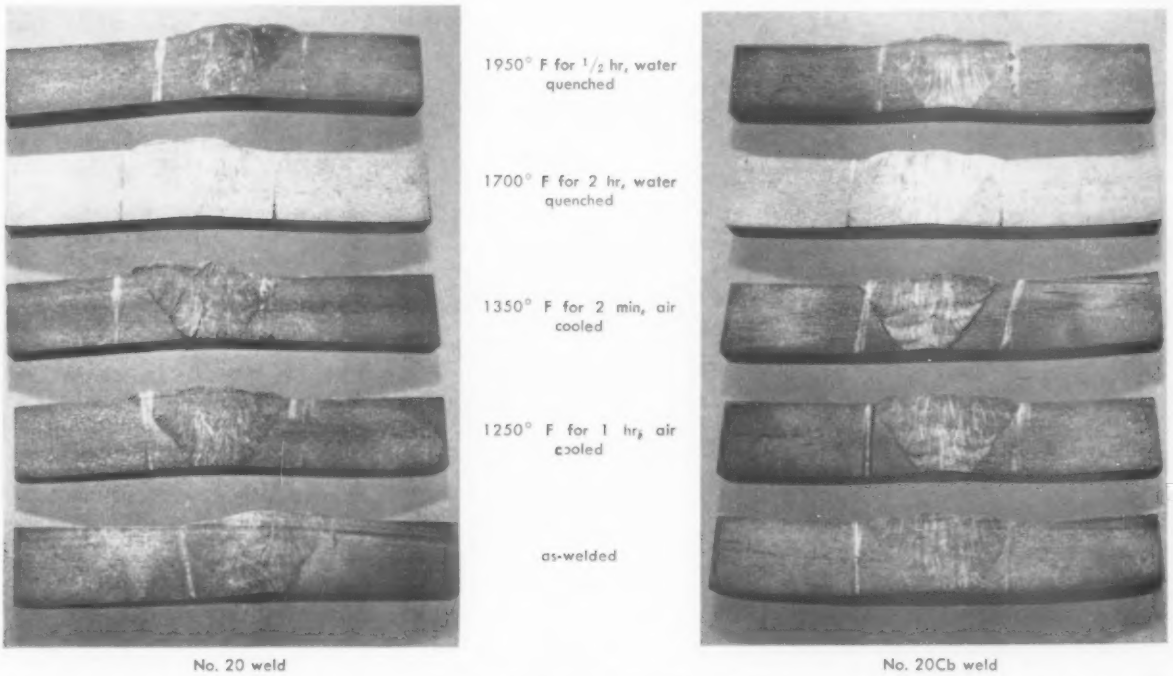
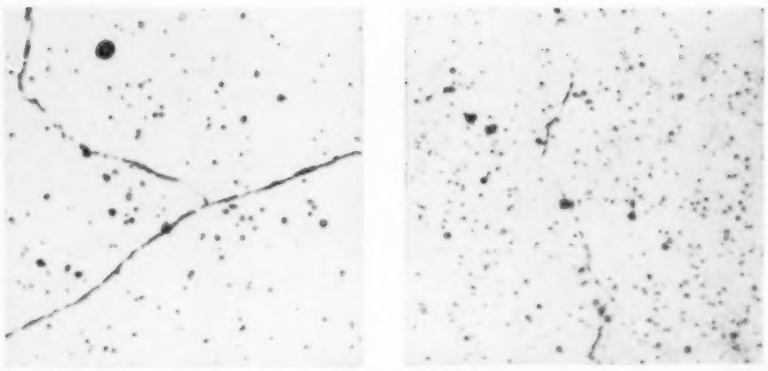

1950° F for $^1/_2$ hr, water quenched
1700° F for 2 hr, water quenched
1350° F for 2 min, air cooled
1250° F for 1 hr, air cooled
as-welded
No. 20 weld
No. 20Cb weld

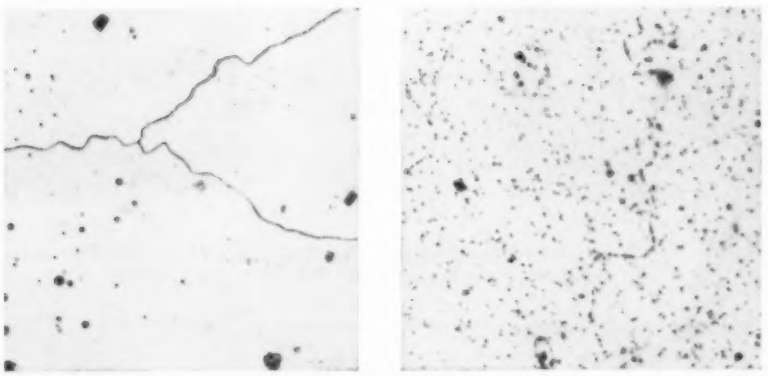
Fig. 9 Transverse specimens in various conditions of heat treatment after the sulfuric acid corrosion test and subsequent bending. Approximately full size



Marble's Reagent X 1000 Marble's Reagent X 1000

No. 20 No. 20Cb

Fig. 10 The microstructure of the welds, as-deposited



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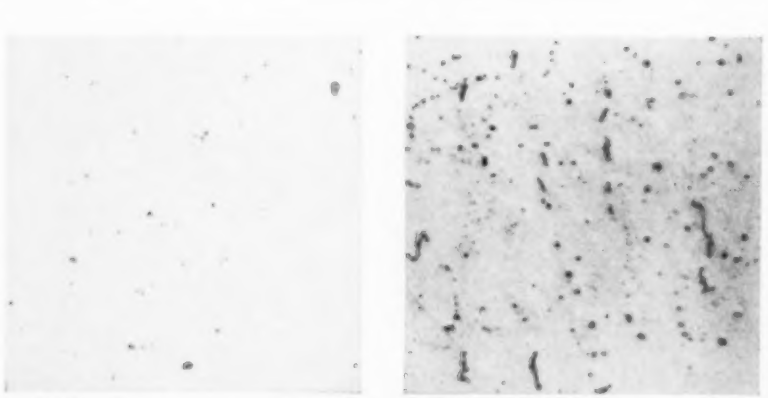
No. 20 No. 20Cb

Fig. 11 Weld microstructures after heat treatment at 1350° F for 2 min, air cool. Note the continuous grain boundary precipitate in the No. 20 structure



Marble's Reagent X 1000 Marble's Reagent X 1000

No. 20 No. 20Cb

Fig. 12 The solution annealed (1950° F for $^1/_2$ hr, W.Q.) microstructure of the welds. No. 20 is fully austenitic while No. 20Cb weld metal contains columbium carbides in an austenitic matrix

jected to the acidified copper-sulfate test after a sensitizing heat treatment at 1250° F. This photomicrograph was taken at the center of the test specimen and is in the unetched condition.

## Discussion

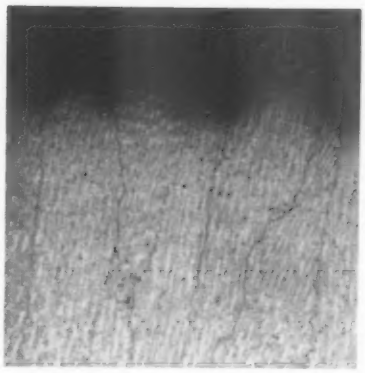
The results of this program indicate that No. 20Cb weld metal is subject to a lesser degree of intergranular attack in all of the corrosion tests, even though the calculated rates, in mils per year, were slightly higher in some cases than those of the corresponding No. 20 specimens. It may be well to point out here that this program was primarily designed to determine the effect of columbium additions on the corrosion resistance of the No. 20 welds in several rather severe tests, not necessarily to duplicate corrosive service applications.

The most sensitive procedure employed to detect a difference in degree of corrosive attack between the No. 20 and No. 20Cb welds involved the bending of tested specimens after exposure to the various corrosive media. This is, of course, standard procedure for the acidified copper-sulfate test, but it is not frequently employed after other types of corrosion testing. Actually the reader could be misled if an analysis of these data were attempted simply on the basis of calculated penetrations determined from weight loss.

It is of more than passing interest to note that the above mentioned differences in corrosion properties could indeed be so clearly illustrated, for the carbon content of the No. 20 weld metal approaches the range of an ELC grade of stainless, at only 0.04 percent. At higher carbon levels, a greater difference in corrosion properties might be expected when comparing this weld metal with No. 20Cb.

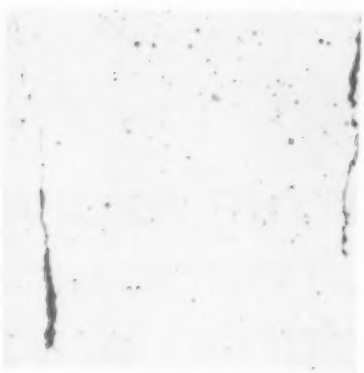
Examination of the microstructure of the as-welded and the sensitized welds revealed that the grain boundary precipitation for both the as-welded and sensitized specimens was heavier and more continuous for the No. 20 weld metal. However, complete analysis explaining the degree of differences in corrosion properties between the No. 20 and No. 20Cb welds from a purely metallographic standpoint was not undertaken.

In regard to multi-pass welds, it should be remembered that only the last pass is in the purely as-welded condition. The preceding passes have been sensitized to some extent by the heat of welding. Since the "as-welded" specimens in this report were taken from multi-pass weld pads, the results are applicable to large weldments in the as-welded condition. Single-pass welds may be slightly better in performance. The data for the as-welded No. 20Cb specimens suggest that this weld metal



Marble's Reagent X 100

Fig. 13 Typical intergranular surface attack. No. 20Cb weld tested in sulfuric acid after heat treatment at 1250° F for 1 hr, air cooled



Unetched X 1000

Fig. 14 Selective intergranular corrosive attack near the center of No. 20 weld specimen tested in the acid copper-sulfate solution after heat treatment at 1250° F for 1 hr, air cooled. (Reduced by $^1/_4$ upon reproduction)

will perform satisfactorily without further heat treatment, but the No. 20 weld metal in the as-welded condition has already become sensitized from the heat effect of subsequent passes.

### Conclusions and Recommendations

1. This investigation has shown that No. 20Cb weld metal is subject to less severe intergranular corrosive attack than the No. 20, particularly in the as-welded and the sensitized conditions. Since this basic difference exists, it is suggested that only No. 20Cb electrodes be used in applications involving stainless No. 20Cb base materials if the ultimate corrosion resistance of the weld metal is to be realized.

2. If the weldment is No. 20Cb throughout, and will not be exposed to sensitizing conditions before being put into service, the as-welded vessel should exhibit satisfactory corrosion resistance.

3. If the welded vessel can be annealed, No. 20 and No. 20Cb welds will have essentially equivalent corrosion resistance. The choice of No. 20 electrodes may be fully justified in this case.

4. In the welding of heavy sections of stainless No. 20 and No. 20Cb base materials, and where conditions of severe restraint present a real danger of cracking, No. 20 electrodes may be the best choice in spite of the lower corrosion resistance of the weld, because the possibility of obtaining a cracked weld must be minimized. In this case, a post-welding heat treatment would be necessary to prepare the weldment for corrosive service.

5. The results of this investigation indicate that annealing may be accomplished by heating the weld to 1700° F and holding for two hours, followed by a water quench. If it is not possible to apply the preferred 1950° F annealing treatment, the 1700° F treatment may be used as a substitute; however, some sacrifice in corrosion resistance will probably result.

*Acknowledgment*

Photographs of the tested specimens were prepared by Mr. E. Petricoin, The Carpenter Steel Co.

# QUALITY CONTROL OF STEELS FOR WELDED PENSTOCKS

BY W. STAUFFER AND A. KELLER

Abstract by **Gerard E. Claussen** of "Essais et Controle des Materiaux et des Pieces Soudes pour Centrales Hydro-Electriques," published in *Rev. Soudure*, **12**, 220–242 (1956).

Dr. Claussen is associated with the Development Laboratories, Linde Company, Newark, N. J.

This article describes the tests used by Escher-Wyss Co. to control the quality of ordinary and high-tensile steel plates. Notch tests are used to a considerable extent. The firm divides steels into the five classes shown in Table 1. Eight subclassifications are distinguished in Class 1, as shown in Table 2. The requirements for the tests in Table 2 are listed in Table 3. Tests of 22 heats of steel of Class 1 showed pronounced differences in notch impact results in Kuntze test results, and in Kommerell bead-bend test results, Table 4. The usual notch impact specimen is the Charpy Vee in these tables. The sharp notch specimen had 0.03 mm radius at the root. The Kuntze specimen is a tensile impact bar 10 mm diam, with annular 60-deg notch 2.5 mm deep. According to Kuntze, the ratio of the reduction of area notched to unnotched should be 0.75 min. Plates

(*Continued on page 365-s*)

Table 1—The Five Classes of Steels Specified by Escher-Wyss

| *Class* | *Yield strength, psi* *Min* | *Max* | *Tensile strength, psi, min* | *Elongation, $C_c$, in a gage length of* $5.65\sqrt{A}$ | $11.3\sqrt{A}$ | *Ratio of yield strength to tensile strength* |
|---|---|---|---|---|---|---|
| 1 | 28,400 | 37,000 | 50,000 | 22 | 28 | 0.55–0.70 |
| 2 | 35,500 | 45,500 | 57,000 | 20 | 25 | 0.60–0.75 |
| 3 | 42,500 | 55,500 | 64,000 | 17 | 22 | 0.62–0.77 |
| 4 | 50,000 | 64,000 | 71,000 | 14 | 19 | 0.64–0.79 |
| 5 | 57,000 | 71,000 | 78,500 | 12 | 17 | 0.66–0.81 |

$A$, cross-sectional area of specimen.

# METALLURGY OF THE WELDING OF CERTAIN AUSTENITIC HEAT- AND CORROSION-RESISTANT ALLOYS

*IIW Paper considers the methods available for welding a series of highly-alloyed materials which have proved useful under many difficult and damaging service conditions*

BY ANTHONY H. WATERFIELD AND R. P. CULBERTSON

SUMMARY. Three corrosion-resistant alloys and three heat-resistant alloys—all highly-alloyed materials—are considered in this paper. Their development and uses are touched upon.

After a brief description of the methods of preparation for welding, the metallurgical properties of each alloy are considered in turn in the light of their effect on the welding techniques necessary. The fabrication methods for the two types of alloys are discussed in connection with the service to be expected from the alloys.

## Introduction

There are many austenitic, heat- and corrosion-resistant alloys. To some extent nickel-chromium stainless steels can be so classed. We wish to discuss a few alloys developed to withstand severe conditions of heat and corrosion under which stainless steels and other less noble alloys have only a short life, either because the operating temperature is very high or because the liquids to be handled are extremely corrosive.

These are necessarily very highly-alloyed materials, which are known in the USA as "high alloys." They are not all of the same alloy types. Of the alloys we wish to discuss, four are nickel-base, one is cobalt-base and one iron-base.

To illustrate more clearly the types of service which the alloys can meet, it may be useful to outline their history in the context of the problems they were developed to solve.

A material able to withstand hydrochloric acid was still being sought long after other acid-resisting requirements had been met. Earlier work suggested that a nickel-base alloy would be useful and that the additions of molybdenum would be beneficial. The first commercial alloy able to withstand all concentrations of hydrochloric acid was developed in the USA. It was a ternary nickel-molybdenum-iron alloy resistant to all concentrations of hydrochloric acid up to 70° C. But the need for a material resistant to the boiling acid involved a continuation of the research and an alloy of 26 to 30% molybdenum and about 5% iron was developed.

This nickel-molybdenum alloy is the first of those to be described. Apart from its outstanding resistance to hydrochloric acid at all concentrations and temperatures, this alloy has excellent resistance to sulphuric and phosphoric acids as well as a variety of nonoxidizing salts, organic acids and alkalies.

Being commercially available not only as castings but in almost all wrought forms (an exception to date is seamless tubing), this nickel-molybdenum alloy has been widely used in pickling baths, in pumps, and valves handling corrosive liquids, in the organic-synthesis field where corrosive catalysts are involved, in the petroleum field as a lining for isomerization towers.

While the corrosion resistance of the nickel-molybdenum alloy is exceptional, its use under oxidizing conditions must be avoided. Further research was needed to overcome this difficulty and naturally the effect of adding chromium was investigated. It was found that by replacing some of the nickel and molybdenum with chromium, an alloy was obtained with quite exceptional resistance to a wide range of corrosive media. This nickel-molybdenum-chromium alloy contains about 16% molybdenum and 15% chromium, as well as 5% iron and a significant (4%) amount of tungsten added to improve both the mechanical properties and the corrosion resistance.

This nickel-molybdenum-chromium alloy has good resistance to hydrochloric acid and chlorine salts and is one of the few materials adequately resistant to wet chlorine gas, hypochlorite solutions, and strongly oxidizing chloride compounds such as ferric or cupric chlorides. It has good resistance to phosphoric, sulphuric, acetic and nitric acids and has fair resistance to many mixed acids such as nitric-hydrofluoric and nitric-sulphuric. It is indeed one of the most universal corrosion-resistant alloys commercially available and is obtainable in the same range of cast and wrought forms as the nickel-molybdenum alloy.

Chemical firms use this alloy for vessels in which a variety of reactions may take place. It is widely used in the rayon industry where any contamination would lead to thread discoloration, which cannot be tolerated. It has found applications in heat exchangers using sea water as a coolant for corrosive liquids such as aluminum chloride solution, for example. Its resistance to sea water, which does not tarnish a reflecting surface of this alloy, has led to its use for searchlight reflectors for ships and lighthouses. Its general resistance resulted in its extensive use for pickling equipment. Its exceptional resistance to wet chlorine combined with high strength has led to its wide use for the key parts of chlorinating units for swimming baths, sewage disposal units and drinking water systems.

The next alloy to be discussed was developed as a compromise between the nickel-molybdenum-chromium alloy and stainless steel: to have resistance

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to severe corrosion conditions approaching that of the former but to have working characteristics nearer to those of stainless steels. Over 250 alloys in the nickel-molybdenum-chromium-iron system were tried in five different media chosen for their specific corrosive action. The best combination of elements from the standpoint of cost and over-all corrosion resistance contained about 45% nickel, 6% molybdenum, 22% chromium, 2% columbium plus tantalum and the balance iron. It is available in all wrought forms except seamless tubes.

This alloy was placed on the market about six years ago. It has already been used rather extensively in the USA in the wood pulp industry, being ideal for use in sulphite digesters. Its relative freedom from stress corrosion and pitting makes this alloy preferable to Type 316 stainless steel for this application and its range of corrosion resistance makes it most attractive for use in the new duplex pulping processes in which the first part of the cook is in weak or strong sulphurous acid while the remainder is under alkaline conditions.

The three alloys so far described have all been developed for corrosion resistance though the first two of them also have excellent heat resistance, maintaining good strength up to 650° C (1200° F). The other three alloys to be dealt with in this paper are primarily heat-resistant alloys though one of them, the cobalt-base alloy, also has exceptionally good corrosion resistance in oxidizing media.

The first heat-resistant alloy to be considered is iron base. It belongs to the class known in the USA as N-155 and it can be described as a Fe-Cr-Ni-Co alloy containing, apart from iron, about 21% chromium, 20% nickel, 20% cobalt, together with 3% molybdenum, 2.5% tungsten, and 1% columbium plus tantalum. It is available in all wrought forms, except seamless tubes and (with slightly higher carbon) as castings. The alloy has good strength properties up to 815° C (1500° F) and oxidation resistance at temperatures as high as 1100° C (2010° F). It has been used extensively in aircraft jet engines, as castings for blades; as forgings for blades, rotors and bolts; and in sheet form, for tail pipes. It is a versatile and economical alloy.

The cobalt base (Co-W-Ni-Cr) alloy was a development from a family of corrosion-resistant and high-temperature alloys. It contains about 20% chromium, 15% tungsten, 10% nickel. It was produced to provide a sheet material of high room-temperature ducility with good high-temperature strength and oxidation resistance up to 980° C; it is also available in bar form. These properties have led to an extensive usage in jet turbines.

A valuable feature of this alloy is its excellent resistance to chemical oxidizing agents, in particular to wet chlorine and in certain concentrations and temperatures to hydrochloric acid, nitric acid and mixtures of these acids.

The last heat-resistant alloy to be discussed is a Ni-Cr-Mo-Fe alloy containing 45% nickel, 22% chromium, 9% molybdenum and the balance iron. It is available as sand and investment castings and in most wrought forms. Since its introduction in 1951, it has been widely used in sheet form in such aircraft components as jet engine tail pipes and afterburners.

As would be expected, this chromium-bearing, nickel-base alloy has exceptional resistance to oxidation at elevated temperatures. It has been successfully applied to furnace parts operating at temperatures as high as 1250° C (2275° F).

This brief description of some of the applications of these alloys will have implied that they are capable of being welded. Indeed, all the joining processes generally used for stainless steel are applicable with or without some slight variations. We aim to discuss the fusion welding of these highly-alloyed materials with particular ref-

Table 1—Nominal Compositions of Wrought, High-Temperature Alloys, Percent

| *Element* | *Ni-Mo Alloy* | *Ni-Mo-Cr Alloy* | *Ni-Mo-Cr-Fe Alloy* | *N-155 Fe-Cr-Ni-Co Alloy* | *Co-W-Ni-Cr Alloy* | *Ni-Cr-Mo-Fe Alloy* |
|---|---|---|---|---|---|---|
| Chromium | ... | 15.5 | 22.0 | 21 | 20.0 | 22.0 |
| Nickel | Bal. | Bal. | 45.5 | 20 | 10.0 | Bal. |
| Iron | 5.0 | 5.5 | Bal. | Bal. | 3.0* | 18.5 |
| Cobalt | 2.5* | 2.5* | 2.5* | 20 | Bal. | 1.5 |
| Molybdenum | 28.0 | 16.0 | 6.5 | 3.0 | ... | 9.0 |
| Tungsten | ... | 4.0 | ... | 2.5 | 15.0 | .6 |
| Carbon | 0.05* | 0.08* | 0.08* | 0.12 | .10 | .10 |
| Manganese | 1.0 | 1.0* | 1.5 | ... | 1.5 | 1.0* |
| Aluminum | ... | ... | ... | ... | ... | ... |
| Titanium | ... | ... | ... | ... | ... | ... |
| Cb + Ta | ... | ... | 2.2 | 1.0 | ... | ... |
| Electric resistivity, microhms/cm | 135.1 | 139.0 | 112.0 | 93.3 | 88.7 | 118.3 |

* Maximum

Fig. 1 Nickel-molybdenum alloy—Solution treated. X 100

Fig. 2 Nickel-molybdenum alloy as-welded by metallic arc. X 250

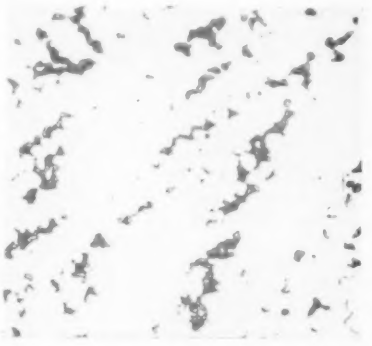

Fig. 3 Nickel-molybdenum alloy cast. X 300

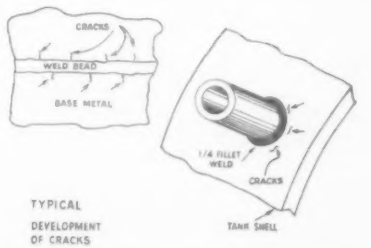


Fig. 4 Typical examples of cracking in base metal

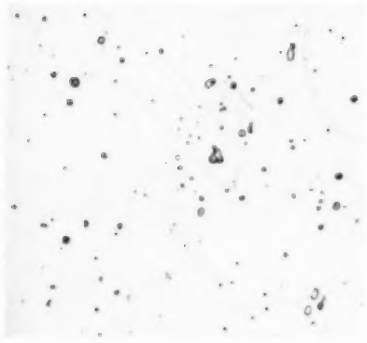

Fig. 5 Nickel-molybdenum-chromium alloy—Solution treated. X 300

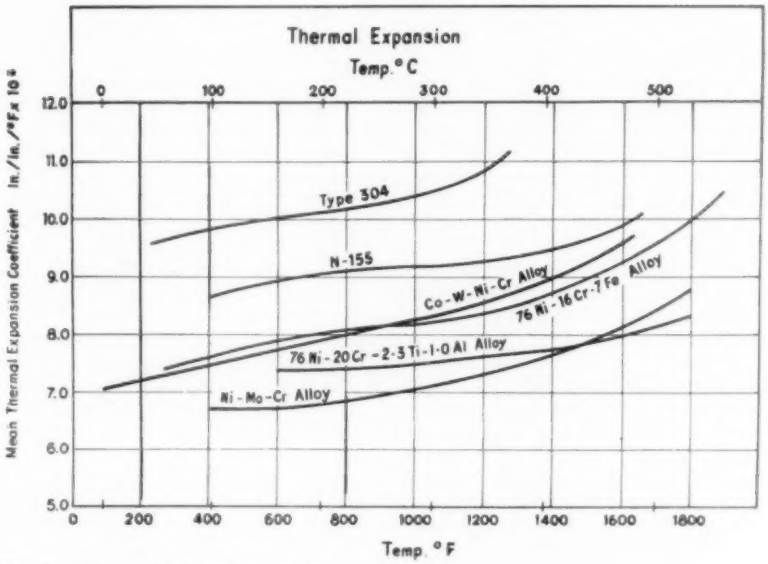


Fig. 6 Curves of thermal expansion

erence to the metallurgy of the base metal.

The nominal compositions of the wrought high-temperature alloys considered are given in Table 1. This shows also on the bottom line the electrical resistivity of the alloys.

### *General Preparation for Welding*

In all instances, immediately before welding, the welding surface and adjacent base metal should be thoroughly cleaned down to bright metal. A solvent material may be used to help remove any grease and oil. The surface should be wiped clean before welding.

Material thinner than $^1/_{10}$ in. (2.5 mm) can be welded from one side by using proper edge spacing to allow full penetration. Care should be exercised to eliminate nonuniform penetration as this may leave undesirable crevices and voids in the underside of the joint which may become centers of accelerated corrosion. In material used for high-temperature applications, irregular penetration creates stress raisers which may lead to mechanical failure.

Material $^1/_{10}$-in. (2.5 mm) thick and heavier should be bevelled and welded from both sides. When joining material of dissimilar thicknesses, the heavier section should always be bevelled for ease of welding. Welding from both sides is recommended whenever possible but, if not practicable, the joint spacing should be increased and a copper backing bar used, and currents higher than normal should then be employed to obtain complete penetration.

Correct alignment and careful edge preparation are particularly important in this class of alloys. Any misalignment causes variation in bead contour, gap width and stresses in the weld area, factors contributing to cracking in the weld joint. Correct fits are easiest to obtain if the material is bevelled by machine. The sheared edges of sheet or plate should be ground back to remove all stressed material. Thermal cutting and bevelling is not recommended. Since the initial metal cost is high, careful preparation to assure good welds is economically justified.

The standard joint designs used in the fabrication of fusion welded equipment can be used with slight modifications to allow for automatic welding operations, such as submerged arc or inert-gas-shielded arc. Larger clearances than for steel should be provided in V or U or J grooves because these highly-alloyed materials do not have the fluidity of steel, and the bevel angle and the minimum bottom radius need to be increased. In general, the V-joint preparation is used for butt welds in plate thicknesses up to $^1/_4$ in. (6 mm) and a U-joint for greater thicknesses.

The use of jigs and fixtures for assembly and subsequent welding provides definite economies in reduced welding cost, greater speed in welding, and ease of producing welds of uniformly high quality. It is generally desirable to provide a backing bar of some sort which serves as a chill, reducing the area of the heat-affected zone and helping to obtain a more uniform bead penetration by eliminating excessive hangthrough of the weld bead. The backing bar is usually grooved to permit good bead contour.

## Corrosion Resistant Alloys

### *Nickel-Molybdenum Alloy*

The nickel-molybdenum alloy is comprised of an austenitic structure with

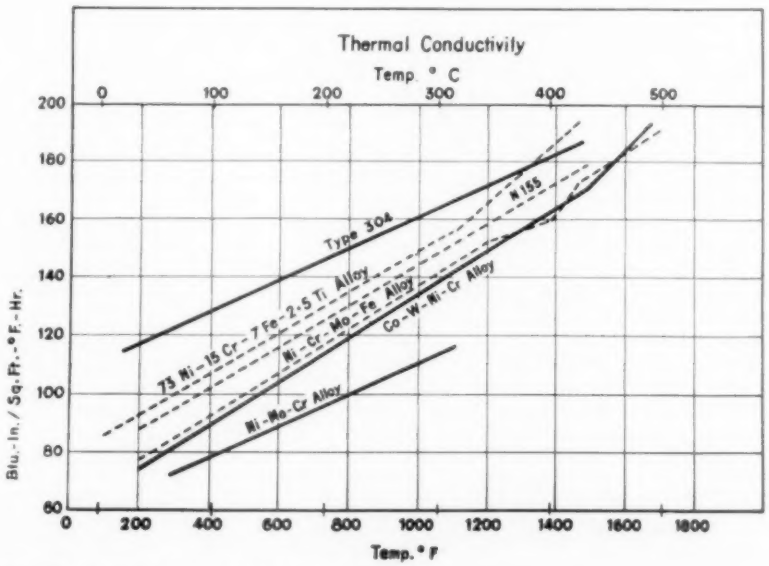


Fig. 7 Curves of thermal conductivity

few, well dispersed and spheroidized carbides of the $M_6C$ type, when in the solution heat-treated condition (Fig. 1). During the welding operation, a precipitate tends to be formed at the grain boundaries, which, in certain corrosive environments, decreases the corrosion resistance of the heat-affected area. The weld metal may be assumed to be analogous to cast metal, and hence, the microstructures may show all of the characteristics of cast metal exhibiting a pronounced dendritic structure (compare Figs. 2 and 3).

This material has a range of low ductility from 540–870° C (1000–1600° F), (when the elongation drops sharply from 40 to 10%), and physical properties of low thermal conductivity and high electrical resistivity. These factors have a very decided effect on the weldability of the alloy and require that suitable welding techniques be used. The major welding problem associated with this material is cracking of the base metal either transverse to the weld and extending from the edge of the weld approximately $\frac{1}{8}$ in. into the base metal, or longitudinal to the weld and occurring approximately $\frac{1}{8}$ in. from the edge of the weld (Fig. 4). The longitudinal cracks are usually associated with restraint of the weld joint while the transverse cracks are due to the thermal condition and restraint of the weld.

The preparation of the weld joint is very critical in these highly-alloyed materials and a welding sequence should be used that will produce a minimum of stress in the weldment. Because of the poor thermal conductivity of this material, a rapid heat build-up is incurred during welding; therefore, stringer-bead welding technique should be used without weaving. The weldment should be kept as cool as possible at all times. When welding with the manual metallic-arc electrodes, the weld may be swabbed with a damp rag immediately following deposition. When using the inert-gas-shielded tungsten-arc process, it is important to use adequate gas flow (30 cu ft—850 l—per hr) and to protect the back of the weld; otherwise, porosity may be incurred in the deposit from aspiration of air into the weld.

This material, because of its low-carbon content (Table 1), is more resistant to sensitization in the heat-affected zone than the higher-carbon versions and is less sensitive to cooling rate from the solution heat-treating temperature. However, for maximum corrosion resistance, the weldment should be placed in the solution heat-treated condition. If this is not possible, then welded samples should be corrosion tested in the process to determine the corrosion rate for the material in the as-welded condition.

Fig. 8 Nickel-molybdenum-chromium alloy as welded by metallic arc. X 250

### *Nickel-Molybdenum-Chromium Alloy*

The nickel-molybdenum-chromium alloy is of the austenitic type with fine, well dispersed, spheroidized carbides of the $M_6C$ type, when in the solution heat-treated condition. The $M_6C$ in this alloy is rather complex and of greater quantities than in the Ni-Mo alloy (Fig. 5), since the alloy consists of chromium, molybdenum, tungsten and nickel (Table 1).

This alloy is not as prone to cracking or formation of porosity in the weld as the nickel-molybdenum alloy and, in general, exhibits slightly better welding characteristics. These properties are attributed to the added chromium content of this alloy. This alloy has slightly lower tensile strength, yield strength and elongation than the nickel-molybdenum alloy. Although there is a drop in elongation in the range 480–980° C (900–1800° F), this is not as severe as in the case of the nickel-molybdenum alloy. Although this allows more latitude in the welding and fabricating of this alloy, the same general rules apply as for the nickel-molybdenum alloy.

This alloy has low thermal conductivity, high electrical resistivity, and a high thermal coefficient of expansion (Table 1 and Figs. 6 and 7). During welding, this alloy is slightly more prone to develop grain-boundary precipitate in the heat-affected zone than the nickel-molybdenum alloy. Because of this phenomenon, if solution heat-treatment of the weldment is not possible, it is important to subject as-welded samples to the corrosive media in which the material is to be used to gain an accurate corrosion rate for the material.

A comparison of the microstructures of the alloy in the as-welded and solution heat-treated conditions may be made by comparing Figs. 5 and 8. The weld structure (like the cast structure) exhibits the same pronounced dendritic structure as the nickel-molybdenum alloy with slightly more eutectic carbide (dark gray) present.

### *Nickel-Molybdenum-Chromium-Iron Alloy*

This material in the solution heat-treated condition is essentially austenitic in structure with some $M_6C$ and MC-type carbides dispersed throughout the structure. The columbium and tantalum contents have the effect of stabilizing the alloy during welding operations; thus, the alloy possesses a high degree of resistance to heat-affected zone corrosion in the as-welded condition.

The alloy is not as prone to loss of ductility in the temperature range of 540–980° C (1000–1800° F) as the nickel-molybdenum alloy, and therefore, is not as critical to thermal cracking in the weld or base material. To provide the condition of best corrosion resistance, the weldment should be solution heat-treated; however, if this is not practical, as in the case of lined vessels, the corrosion rate calculations for the material must be based on as-welded material.

## Discussion of Corrosion-Resistant Alloys

The principal use of the foregoing alloys is for corrosion-resistant applications found in the many processes now used by industry. These alloys are all of the austenitic type, that is, they consist of a face-centered cubic matrix, which is a nickel-rich solid solution plus some intermetallic constituents. The alloys in the solution heat-treated condition are generally considered to be of two phases, consisting of an austenitic matrix and primary carbides of the $M_6C$ type, and, in this condition, the alloys display their maximum corrosion resistance.

The nickel-molybdenum alloy forms an intermetallic precipitate in the temperature range of 590–1040° C (1100–1900° F). The formation of this precipitate is slow, except where conditions of cold work prevail. Since the precipitate forms slowly, this alloy does not suffer loss of corrosion resistance in the heat-affected zone as readily as many other alloys in this class, and also, the cooling rate of this alloy from the solution heat-treating temperature is not as critical.

The nickel-molybdenum-chromium alloy forms a precipitate of the $M_6C$ type in the temperature range of 480–1040° C (900–1900° F). This formation is very rapid, therefore the cooling rate from the solution heat-treating temperature is critical and if possible the weldment should be water-quenched or spray-quenched from the solution heat-treating temperature.

Since the alloy does sensitize in the heat-affected zone during welding, the weldment should be solution heat-treated for maximum corrosion resistance.

The nickel-molybdenum-chromium-

iron alloy forms a precipitate of the MC and $M_6C$ type in the temperature range of 590–1040° C (1100–1900° F). Since this alloy is stabilized with columbium (niobium) and tantalum, the corrosion resistance is not materially affected by welding and the alloy can usually be used in the as-welded condition, depending on the corrosive environment.

These corrosion-resistant alloys are readily welded by the metallic-arc process using covered electrodes of the same composition as the base material. The inert-gas-shielded tungsten-arc process is used very successfully with materials up to 12 gage (0.109 in. or 2.8 mm in thickness). The inert-gas-shielded tungsten-arc process is not recommended for material thicknesses of over $^1/_8$ in. (3.2 mm) as the heat energy released to the base material is greater than if the metallic-arc process were used. In all welding operations, the heat input should be at a minimum level required to produce a satisfactory weld joint. In all instances, the oxyacetylene welding process should be avoided when joining these materials.

## Heat-Resistant Alloys

### *N-155 Alloy*

This is a high-strength austenitic-type alloy containing a major proportion of iron. This composition was designed to be resistant to embrittlement after extended periods of exposure at elevated temperatures. The austenitic structure was chosen because it is inherently ductile, strong at elevated temperatures, adaptable to work-hardening processes, and capable of forming precipitation-hardening systems, thus improving hot strength.

The photomicrographs of this alloy would show a typical austenitic structure with well dispersed and spheroidized carbides in the solution heat-treated condition. In the as-welded condition, the structure is dendritic with an interspersed eutectic carbide. This alloy is prone to microfissuring or cracking in the weld bead, possibly because of the low-melting eutectic formation along the dendrites. Therefore, it is important to have a minimum of restraint in the weld area, a minimum of residual heat in the weldment and to use a stringer-bead welding technique and low heat input. It is extremely important to use a well-planned welding sequence and a joint-alignment fixture to produce a minimum of restraint in the weld during solidification.

This alloy should be in the solution heat-treated condition before fabrication as this is the condition of maximum ductility. If the alloy is to be subjected to deep drawing or severe forming, the intermediate anneals will be necessary since the alloy work hardens during forming operations. As heat treatment after severe forming operations may be accompanied by cracking in the deformed areas, this condition is best alleviated by intermediate anneals during forming.

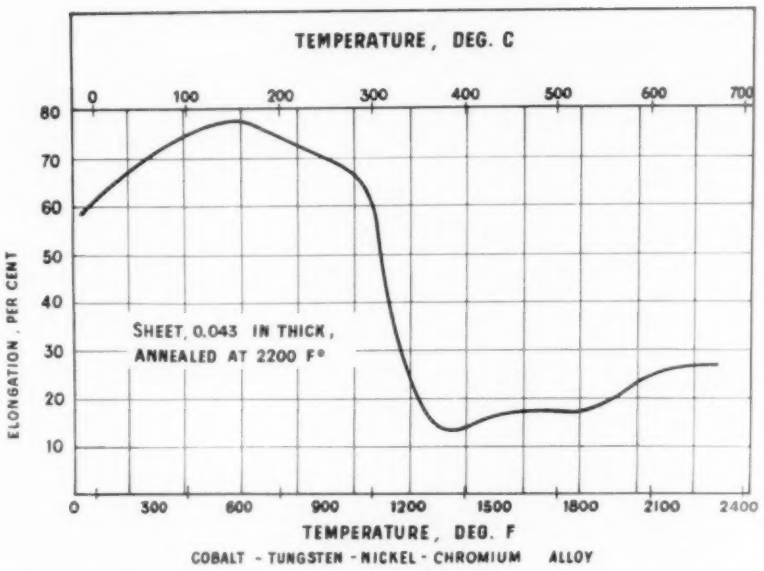


Fig. 9 Cobalt-tungsten-nickel-chromium alloy—Elongation-temperature curve

### *Cobalt-Tungsten-Nickel-Chromium Alloy*

This alloy has an austenitic structure with well dispersed spheroidized $M_6C$ in the solution heat-treated condition. During the development of this alloy, it was found that nickel was beneficial in raising the cold ductility of the alloy. Tungsten was found to substantially strengthen the alloy both by solid solution strengthening and precipitation hardening.

This alloy possesses higher mechanical properties, such as tensile strength, yield strength and elongation, than those shown by the other alloys we have discussed. This material has good weldability and is easily fabricated; however, it is somewhat prone to hot-short cracking (Fig. 9), similar to nickel-molybdenum alloy. The same welding techniques should be exercised as for nickel-molybdenum alloy. The weld deposit exhibits a similar columnar dendritic structure and eutectic carbides.

### *Nickel-Chromium-Molybdenum-Iron Alloy*

The nickel-chromium-molybdenum-iron alloy was somewhat of a compromise in that it was developed to have the high-temperature strength and oxidation resistance of the nickel-chromium-molybdenum alloy and the relatively good ductility and resistance to embrittlement of the foregoing nickel-molybdenum-chromium-iron plus columbium-tantalum alloy (Table 1). Figure 10 shows the excellent oxidation resistance of this alloy which is maintained to 1150° C (2100° F).

Although the stress to rupture strength is slightly lower than N-155 alloy [100-hr life, 816° C( 1500° F), 12.7 kg/sq mm (18,000 psi)] the short-time properties are higher, e.g., Ni-Mo-Cr-Fe alloy at 816° C (1500° F) has an ultimate tensile strength of 33.7 kg/sq mm (48,000 psi) and 37% elongation, while N-155 alloy has an ultimate tensile strength of 25.3 kg/sq mm (36,000 psi), and elongation of 39%.

This alloy derives its strength primarily from solid-solution strengthening, but exhibits precipitation in the 650–950° C (1200–1700° F) range. The aging is not sufficiently strengthening to warrant its specific production by heat-treatment.

This alloy is of the austenitic type with well dispersed spheroidized carbides of the $M_6C$ type in the solution heat-treated condition. It has good weldability and can be fabricated readily and is not prone to hot-short cracking or weld porosity. The weld exhibits the pronounced dendritic structure typical of the "high alloys."

To be most readily fabricated, the alloy should be in the solution heat-treated condition. However, after welding, the alloy need not be solution heat-treated unless desired, as the welding will not materially affect the oxidation rate of the material.

## Discussion of High-Temperature Alloys

These alloys have found wide usage as high-temperature materials in the temperature range of 730–1200° C (1350–2000° F). The largest usage has, of course, been in the aircraft industry. These alloys are noted for high strength and oxidation resistance at elevated temperatures (Fig. 10). To be formed

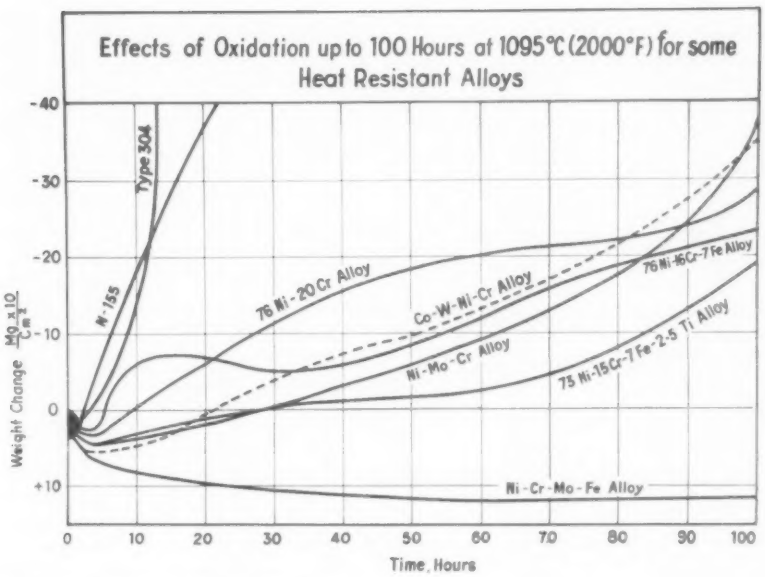


Fig. 10 Effects of oxidation of some heat-resistant alloys

most easily, the alloys should be in the solution heat-treated condition as this is the condition of maximum ductility. If, during fabrication, severe forming or drawing of the alloy is necessary, it is advisable to do the forming operation in several steps with intermediate solution heat treatment of the material, as these alloys work harden rapidly. If the alloy is not given intermediate heat-treatment during forming operations, cracking may occur in the highly stressed areas on subsequent heating.

These alloys are readily welded with metallic-arc covered electrodes and the inert-gas-shielded tungsten-arc process. The same general welding procedure should be adhered to as for the corrosion-resistant alloys; i.e.: (1) use stringer-bead technique (no weaving), (2) keep weldment as cool as possible, (3) use a minimum of heat input, (4) no preheat nor postheat of weldment, and (5) minimum of restraint of the weld joint.

## Conclusion

From the foregoing discussion, it will be realized that when using corrosion-resistant alloys it is important to test the corrosion resistance of the alloy in the same conditions of fabrication and operation as will be met in service. A selected portion of the assembly, or model of it, can be fabricated by the methods proposed, heat-treated and welded. If the part gives good service, then it is safe to assume that the complete assembly will also give good service. This preliminary testing is time consuming; however, conditions vary so much from one chemical plant to another that despite the extensive knowledge which has been assembled concerning the effect of welding on the behavior of these alloys, the exact performance in any given condition can not always be predicted.

# QUALITY CONTROL OF STEELS FOR WELDED PENSTOCKS

(Continued from page 359-s)

Table 2—Eight Subclasses Under Class 1

| Service | | Fabrication | | Stress-relief | Quality | Notch impact test requirements | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A | B | | D | | | G |
| Low stress | High stress | Cold work | Welding | heat treatment | sub-class | As-received | Stress-relieved | C Normalized | Water-quenched | E Aged | F Annealed | Sharp notch |
| X | .. | .. | .. | .. | Ia | .. | .. | .. | .. | .. | .. | .. |
| .. | X | .. | .. | .. | Ib | X | .. | .. | .. | .. | .. | .. |
| .. | X | X | .. | .. | Ic | X | .. | .. | .. | X | .. | .. |
| .. | X | X | .. | X | Id | X | (X) | .. | .. | .. | .. | .. |
| .. | X | .. | X | .. | Ie | X | .. | X | X | .. | X | X |
| .. | X | .. | X | X | If | X | (X) | .. | .. | .. | X | .. |
| .. | X | X | X | .. | Ig | X | .. | (X) | X | X | X | X |
| .. | X | X | X | X | Ih | X | (X) | .. | .. | .. | X | .. |

*D*, quenched in water from 920° C. *E*, 10% cold work then aged ½ hr at 250° C. *G*, tested as-received.
Requirements are 8, 7 and 6 mkg/cm² at +20, 0 and −20° C, respectively, for *A* to *D*.
Requirements are 6, 4 and 2 mkg/cm² at +20, 0 and −20° C, respectively, for *E* and *F*.
Requirements are 6, 5 and 4 mkg/cm² at +20, 0 and −20° C, respectively, for *G*.

3 and 7 in Table 4 were satisfactory on the basis of both the Kuntze and notch impact tests. The other five plates were mediocre in quality.

Covered electrodes of 6020 and low-hydrogen types are used in fabricating the lower tensile steels, while low hydrogen types only are used for the high-tensile steels. The following points are considered in selecting electrodes.

Table 3—Notch Impact Requirements, Mkg/cm² for Classes 2 to 5 of Table 1

| Class | A to D | E | F | G |
|---|---|---|---|---|
| 2 | 8-7-6 | 8-7-6 | 6-5-4 | 6-5-4 |
| 3 | 8-7-6 | 6-5-4 | 6-5-4 | 6-5-4 |
| 4 | 7-6-5 | 5-4-3 | 5-4-3 | 5-4-3 |
| 5 | 7-6-5 | 5-4-3 | 5-4-3 | 5-4-3 |

First, the weld metal should have about the same chemical composition and mechanical properties as the plate or casting. A close match is desirable so that the weld metal or heat-affected zone is not forced to yield excessively

(Continued on page 372-s)

# NI-CR-B BRAZING OF A HIGH-TEMPERATURE ALLOY

*Suitable technique established to produce consistently sound high-strength brazed joints in a high-temperature alloy containing titanium without plating the surfaces to be brazed*

BY GEORGE AGGEN, ROGER A. LONG AND EDWARD E. REYNOLDS

SYNOPSIS. A brazing investigation was conducted on sheet and bar specimens of A-286, an iron-base precipitation-hardening high-temperature alloy. Brazing was performed in a continuous-belt furnace under a dry hydrogen atmosphere. A Ni-Cr-B brazing alloy meeting AMS-4775 specifications was used in joining all the specimens.

The paper includes descriptions of the brazing furnace and brazing cycles required to obtain optimum joints in the specimens. Though the A-286 alloy contains about 2.0% titanium and 0.2% aluminum, it was not found necessary to plate the surfaces in order to obtain satisfactory joints. This is contrary to findings given in previously published papers in this field. A description of the simple and inexpensive surface preparation that was utilized is given in the paper.

The quality of the brazed joints was evaluated by metallographic examinations and mechanical tests. These tests include smooth- and notched-bar rupture tests at 1200° F and short-time tensile tests at room temperature, 1200 and 1300° F. Metallographic examinations were also made in order to determine the effects of the brazing alloy and the brazing time-temperature cycles upon the microstructure of the high-temperature alloy. These were correlated with the results obtained from the mechanical tests.

Three types of specimens were evaluated by mechanical tests and metallographic examinations. These were:

1. *Surface-Brazed Specimens.* A thin coating of the brazing alloy was applied to the surface of fully machined V-notch and smooth-bar rupture specimens. The properties of these specimens were evaluated and compared with those of blanks which were subjected to identical machining and heat-treating cycles but were not coated with the brazing alloy. Both sets were tested in three conditions of heat treatment performed after the brazing cycle. These and additional tests made it possible to determine the individual effects of the brazing cycles, the postbrazing heat treatments and the presence of a thin coating of the brazing alloy upon the properties of the A-286 alloy.

2. *Butt-Brazed Bar Specimens.* Partially machined smooth-bar rupture and tensile specimens were butt brazed using several combinations of furnace belt speeds and brazing clearances. The effects of these brazing variables were evaluated by metallographic examinations, rupture tests at 1200° F and short-time tensile tests at room temperature, 1200 and 1300° F.

3. *Double-Lap Sheet Specimens.* Sheet samples were prepared and brazed to form double-lap tensile specimens. Shear strengths of the joints were determined at room temperature, 1200 and 1300° F. These tests were performed on joints having two different clearances and after three postbrazing heat treatments.

The results of the investigation indicate that the brazing time-temperature cycle somewhat impairs the 1200° F rupture properties of the high-temperature alloy, but that these properties can be largely recovered by proper postbrazing heat treatment. Microstructural changes introduced at the surfaces of the base metal by the brazing alloy were shown to result in superior elevated-temperature properties. The strengths of the brazed joints were satisfactory, but not as high as those of the base A-286 alloy.

## Introduction

Brazing for joining jet engine components to operate at elevated temperatures has become significantly useful during recent years. Factors contributing to the use of brazing in these applications have been the development of furnaces capable of protecting surfaces to be brazed and the development and utilization of brazing alloys possessing good strength and oxidation resistance at elevated temperatures.

Without exception all the iron-, nickel- and cobalt-base alloys commonly used in high-temperature applications contain 10 to 20% chromium. Some of these, particularly the newer iron- and nickel-base alloys, also contain 1 to 3% of readily oxidized elements such as aluminum and titanium. The presence of these elements has seriously interfered with the procurement of consistently sound brazes in the past, presumably due to the formation of oxides at the surfaces which prevent uniform wetting by brazing alloys.

This oxidation obstacle to successful brazing has been partially overcome through the use of very dry hydrogen atmospheres with dew points of −60° F and lower. This atmosphere generally affords adequate protection to alloys containing only chromium but does not adequately protect those containing substantial amounts of titanium and aluminum. For these latter alloys it is generally necessary to plate the surfaces to be brazed with iron or nickel. Brazing in vacuum is also being investigated as an alternate means of atmospheric protection. It appears that extremely good vacuums will be required to successfully braze alloys containing appreciable amounts of aluminum and titanium.

A number of brazing alloys which appear to have good elevated temperature characteristics have recently been developed and used for such components. These alloys generally contain a nickel base, a substantial amount of chromium and a few percent of elements such as boron or silicon which substantially lower their melting temperature ranges. These brazing alloys generally require brazing temperatures of about 2100° F or higher for satisfactory flow characteristics. An early investigation covering the utilization of one such brazing alloy and the use of dry hydrogen atmosphere was reported by Peaslee and Boam[1] in August 1952.

The present paper will deal with a Ni-Cr-B brazing alloy specified under AMS-4775 when used to join A-286, a widely used elevated-temperature, iron-base alloy specified under AMS-5735. All the brazes were performed in a continuous-belt furnace filled with a dry hydrogen atmosphere. Although A-286 contains about 2% titanium, it was possible to obtain sound brazes without resorting to plating of the joining surfaces.

The primary purpose of this investigation was to determine the effects of the heat-treatment cycle used in brazing

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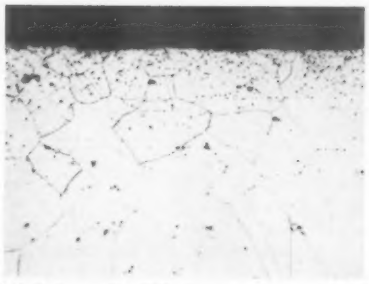
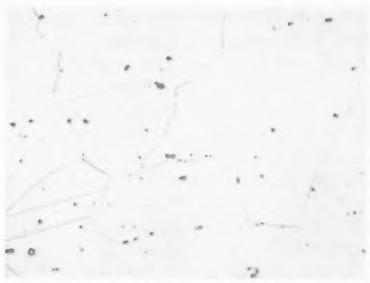


(A) Surface of A-286—heavy concentration of fine dark constituents near surface.



(B) Interior of A-286—relatively free of fine excess constituent.

**Fig. 1 Effects of surface preparation and brazing cycles on microstructure of A-286 alloy. X 250. (Reduced by one-half upon reproduction)**

upon the properties of the alloy. This seemed necessary because the brazing temperature of 2100° F is considerably higher than the highest heat-treating temperature ordinarily recommended for the alloy. Also earlier tests had indicated that A-286 suffered a severe loss in room- and elevated-temperature ductility when brazed in a batch-type furnace. The reduced ductility was believed to be at least partially caused by the relatively long exposures to elevated temperatures that had been used. It was thought that shorter brazing cycles could be most easily evaluated in a continuous-belt furnace.

If deleterious effects were still to result from the shorter brazing cycles, it was desired to devise postbrazing heat treatments which would alleviate these effects. These effects were investigated by subjecting blanks to the brazing heat-treating cycle and to a number of postbrazing heat treatments. Room-temperature tensile tests, creep-rupture tests and short-time tensile tests at 1200° F were conducted on these specimens.

A second purpose of this investigation was to attempt to determine the effects of alloying with the brazing alloy upon the properties and microstructure of the base metal. For this purpose brazing powder was applied to the surfaces of fully machined blanks and these blanks were passed through a typical brazing cycle. Both smooth-bar and V-notched rupture bars were treated in this fashion. In addition, fully machined blanks were passed through the brazing cycle but with no brazing powder applied. These latter samples served as controls. All of these samples were then tested in creep rupture at 1200° F.

A third purpose was to obtain information as to the strength of brazed joints under tension and shear stresses. These properties could serve as guides toward establishing suitable design stresses for brazed joints to be subjected to these stresses. The tensile and rupture strengths of butt joints were determined by butt brazing partially machined bar specimens. The shear strengths were determined from double-lapped joints made on sheet specimens.

## Materials Investigated

The AMS-4775 brazing alloy has a chemical composition approximately as follows:

| | |
|---|---|
| Carbon, % | 1 |
| Silicon, % | 4 |
| Chromium, % | 17 |
| Nickel, % | 70 |
| Iron, % | 4 |
| Boron, % | 4 |

The solidus temperature of the alloy lies at about 1850° F and its liquidus temperature at about 1950° F. Brazing is usually performed at about 2100° F or higher because the alloy has a pronounced tendency to alloy with iron-, nickel- and cobalt-base alloys thereby raising its flow point. The wide melting range of this brazing alloy and its erosive effect upon all alloys commonly used in present jet engine components make it mandatory to observe several precautions in order to obtain satisfactory brazes. These precautions have been ably discussed by Peaslee and Boam[1] and Rose and Lewis.[2] As summarized by Rose and Lewis, three such precautions are:

(*a*) The rate of heating through the melting range must be rapid.

(*b*) The time at brazing temperatures must be kept to a minimum.

(*c*) The amount of brazing alloy at joints must be kept to a minimum.

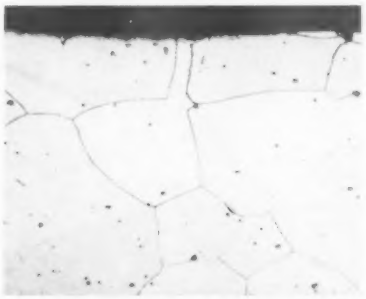
The A-286 high-temperature alloy is an iron-base, precipitation-hardening alloy widely used at present in gas-turbine jet engines principally as wheel forgings, fasteners and sheet components. The nominal chemical composition of the alloy follows:

| | |
|---|---|
| Carbon, % | 0.03 |
| Manganese, % | 1.3 |
| Silicon, % | 0.5 |
| Chromium, % | 14.7 |
| Nickel, % | 25.5 |
| Molybdenum, % | 1.3 |
| Titanium, % | 2.1 |
| Aluminum, % | 0.2 |
| Vanadium, % | 0.3 |
| Iron | Balance |

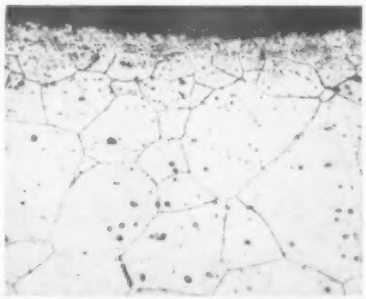
The alloy is usually solution heat treated from 1650 or 1800° F and rapidly cooled. The 1650° F solution heat treatment results in a grain size range of ASTM 7 to finer than 8 and a hardness of about 170 Bhn. The 1800° F solution heat treatment results in a grain size range of ASTM 3 to 8 and a hardness of about 135 Bhn. The solution heat treatment is followed by a precipitation-hardening heat treatment at about 1325° F for 16 hr and air cooled. The aging heat treatment causes an increase in hardness to about 300 Bhn. Age hardening is effected through the formation of a precipitate which is coherent with the face-centered cubic matrix.

## Preparation for Brazing

In common with other alloys containing titanium or aluminum, A-286 has poor wettability even under extremely dry and pure hydrogen atmospheres. Presumably this is attributed to the formation of oxides of these elements at the exposed surfaces under conditions ordinarily thought of as highly reducing. In the case of titanium there is also a distinct possibility that hydrides of titanium form and interfere with wetting characteristics.



(A) Surface of specimen that was machined after subjection to surface preparation and brazing heat-treatment cycle—no excess constituents present at surface.



(B) Surface of specimen that was machined before subjection to surface preparation and brazing heat-treatment cycle—excess constituents present at surface.

**Fig. 2 Longitudinal sections of fractured smooth-bar rupture specimens. No brazing alloy applied to specimens. X 250. (Reduced by one-half upon reproduction)**

Two methods of surface preparation have been used to circumvent this inherent difficulty when brazing alloys containing titanium or aluminum. These are the electrolytic deposition of iron or nickel or deposition of nickel by electroless nickel plating[3] onto the surfaces to be brazed. These methods are being used with satisfactory results but are expensive.

After considerable development work, another method was devised that did not require the use of plating or fluxes. This method was based on the tentative theory that the reactive elements such as titanium and aluminum could be preferentially oxidized at the surfaces of the alloy. The oxidized layer could then be removed by chemical action to form a fresh surface somewhat depleted in these reactive elements and possessing suitable wetting characteristics for subsequent brazing. This is the method used in this investigation.

A furnace with a very dry hydrogen atmosphere was used. It was a continuous-belt furnace with a 5-ft long preheat chamber and a 5-ft long high-heat chamber. The belt speed could be varied from 10 to 150 fph. This furnace design gave the flexibility necessary for a variety of controlled heating cycles. The heating cycle could be reduced to very short times so that during the actual brazing cycle a minimum of oxidation occurred and diffusion to the surface layers was small. The furnace was capable of maintaining in the heat zones dry hydrogen of −80° F dew point or better. Measurements of −90° F dew point of gas leaving the heat chamber were frequent. All hydrogen gas entering the furnace was measured at −100° F dew point or better.

The first series of tests was conducted by oxidizing A-286 specimens by heating in air and removing the formed oxide layer by a nitric-hydrofluoric acid dip. The specimens were subsequently brazed in hydrogen utilizing a fast cycle. The results were not satisfactory. The oxides formed by air heating were heavy and not selective, and the newly exposed surfaces repelled the brazing alloy and turned dark.

A second series of tests was performed in the continuous-belt furnace using a hydrogen atmosphere of higher dew point (−40° F) to perform the oxidizing. The results appeared satisfactory in that a thin dark oxidized coating was obtained which seemed selective. A nitric-hydrofluoric acid mixture was used to remove this oxidized surface layer. Brazing was then performed in the same furnace equipment using dry hydrogen of −80° F dew point and a rapid cycle. The parts were well wetted by the brazing alloy and the color of the A-286 remained bright. These tests were repeated and the results were always satisfactory.

A slower brazing cycle was later used in an attempt to determine if selective oxidation of specific alloying elements was responsible. It was felt that a slower cycle would cause more rapid diffusion of the aluminum and titanium to the surface and would result in a poor quality braze or a darkening of the metal surface. There was a definite tendency for the latter to occur.

The use of controlled oxidation and acid removal of the resultant layer on the A-286 alloy was important to the brazing of this material and gave satisfactory results in later performance. This method has also been applied successfully to 17-7PH alloy which contains about 1% aluminum. It appears to be useful for alloys which contain no more than a total of about 2% titanium and aluminum. The mechanism is of value as it may be applicable to other materials, although it may be limited to furnaces which can be adapted to very short brazing cycles.

The microstructure at the surface of A-286 which has been passed through the brazing furnace is shown in Fig. 1*A*. Figure 1*B* shows a typical microstructure at the interior of the alloy. The larger gray particles with the dark boundaries are TiC (or high-carbon titanium carbonitride), a constituent always present in the alloy. Smaller particles of an excess constituent not normally seen in the microstructure are present at the surface and extend to a depth of about 0.0025 in. This excess constituent has not been identified but is believed to be a titanium compound.

## Effects of Brazing Cycles on Properties

It was desired to determine the effects of the brazing heat-treating cycles upon the tensile and rupture properties of the AMS-5735 alloy. Such data were required because the high temperature of the brazing cycle (2100° F) is considerably higher than that ordinarily recommended for the alloy (1800° F). Based on previous investigations, it was thought that the high temperatures associated with brazing would result in excessive grain growth which lowers tensile strengths and gives inferior rupture ductility and notch life.

Blanks were machined to $\frac{1}{2}$-in. diam shoulders by $\frac{3}{8}$-in. diam reduced sections and passed through the brazing

**Table 1—Partially Machined Blanks**

(A) Stress rupture tests

| *Heat treatments* | *Rupture life, hr* | | *Elongation, %* | *Reduction of area, %* |
|---|---|---|---|---|
| | *V notch* | *Smooth* | | |
| A. 1800° F—1 hr—oil + 1325° F—16 hr—air | 800 | 120 | 10.0 | 23.0 |
| B. B. C.* + 1325° F—16 hr—air | 98 | 489 | 2.3 | 7.9 |
| C. B. C.* + 1650° F—1 hr—oil + 1325 ° F—16 hr—air | 2020 | 471 | 6.2 | 18.2 |
| D. B. C.* + 1800° F—1 hr—oil + 1325° F—16 hr—air | 461 | 476 | 6.8 | 16.7 |

(B) Short-time tensile tests

| *Heat treatments* | *Temperature, ° F* | *0.02% offset yield strength, psi* | *0.2% offset yield strength, psi* | *Ultimate tensile strength, psi* | *Elongation, %* | *Reduction of area, %* |
|---|---|---|---|---|---|---|
| A. 1800° F—1 hr—oil + 1325° F—16 hr—air | 78 | 87,000 | 105,000 | 156,250 | 21.5 | 46.4 |
| B. B. C.* + 1325° F—16 hr—air | 78 | 68,800 | 93,000 | 141,500 | 24.5 | 26.9 |
| C. B. C.* + 1650° F—1 hr—oil + 1325° F—16 hr—air | 78 | 74,300 | 94,000 | 142,700 | 25.0 | 34.1 |
| D. B. C.* + 1800° F 1 hr—oil + 1325° F—16 hr—air | 78 | 67,200 | 94,000 | 143,200 | 26.0 | 34.1 |
| A. 1800° F—1 hr—oil + 1325° F—16 hr—air | 1200 | 76,500 | 94,800 | 115,000 | 12.5 | 25.0 |
| B. B. C.* + 1325° F—16 hr—air | 1200 | 71,000 | 87,400 | 108,300 | 8.9 | 11.6 |
| C. B. C.* + 1650° F—1 hr—oil + 1325° F—16 hr—air | 1200 | 67,100 | 91,000 | 110,700 | 17.3 | 22.3 |
| D. B. C.* + 1800° F—1 hr—oil + 1325° F—16 hrs—air | 1200 | 69,200 | 86,000 | 107,900 | 15.1 | 20.2 |

* B. C., brazing cycle (no brazing alloy applied).

furnace but no brazing alloy was applied. These were solution heat treated and aged in air atmosphere furnaces and machined to standard specimen geometries. The smooth-bar rupture specimens were 0.195 in. diam by 0.8 in. gage length. The notched rupture specimens were 0.275 in. major diameter by 0.195 in. minor diameter. The notches were 0.005 in. radius at the base of the notch by a 60 deg angle. The notch geometry results in a theoretical stress concentration of about 4.2. Several jet engine manufacturers specify that such notched specimens must have longer rupture lives than their counterpart smooth-bar specimens under equivalent testing conditions in order for the material to be acceptable. The tensile specimens were machined to 0.252 in. diam by 2 in. gage length.

The rupture specimens were tested in conventionally designed furnaces utilizing zirconia cores and nichrome windings. Axial loads of 60,000 psi were applied through a 10 to 1 lever arm. Specimens were held at the test temperature of 1200° F approximately one hour before loading. The tensile specimens were pulled in a Riehle tensile testing machine at head speeds of 0.05 ipm to beyond the 0.2% yield strength and at 0.1 ipm to fracture.

The results of the rupture and tensile tests are shown in Table 1 (A) and (B). The properties of conventionally heat-treated specimens from the same heat are shown for comparison.

It can be observed that the brazing cycle has caused a marked increase in the smooth-bar rupture strength. If no intermediate solution heat treatment is used, however, the rupture ductility and V-notch rupture life are quite low. These results were not unexpected based on past experience with the alloy. The rupture properties thus deleteriously affected by the high temperature of the brazing cycle can be largely recovered by resorting to an intermediate solution heat treatment at 1650 or 1800° F. The rupture life remains high when compared to that of the conventionally heat-treated material.

The tensile-test data show that the brazing cycle has resulted in decreases in yield and ultimate strengths and tensile ductility at room temperature and 1200° F. The ductility can be largely recovered by an intermediate solution heat treatment but the loss in strength is permanent. This is believed due to the large grain size resulting from the high temperature of the brazing cycle.

### Surface-Brazed Specimens

The previous tests on the partially machined samples had showed the effects to be expected from the brazing cycle alone. In practice, however, it is often undesirable to machine surfaces after brazing. In order to more closely simulate actual brazing practice, a set of three notched and three smooth-bar rupture specimens were completely machined to finished sizes and passed through the brazing furnace without further preparation. A duplicate set of six specimens was also machined. A thin coating of the brazing alloy was applied to these at the surface of the entire reduced section of the smooth-bar specimens and into the notches of the notched-bar specimens. The brazing alloy was applied in the form of a paste comprising fine particles of the brazing alloy mixed with an organic binder. The particle size varied from −120 to −400 mesh, 20% of which was finer than −320 mesh. The organic binder merely serves to cement the particles together and is volatilized early in the brazing cycle.

After the brazing cycle, these specimens showed uniform increases in diameter of 0.002 to 0.003 in. from the brazing alloy. Since the coating was thin and uniform, neither the notched-bar geometry nor its stress concentration factor was appreciably changed. These surface-brazed specimens were prepared for two reasons; first, to observe the resulting microstructural features and, second, to determine qualitatively if the brazing alloy would noticeably affect the rupture properties.

All twelve specimens were exposed to identical brazing cycles. They were subsequently given three different heat treatments and tested in rupture units at 1200° F and 60,000 psi. The solution heat treatments at 1650 and 1800° F were performed under dry hydrogen and the ages at 1325° F were performed in air atmospheres. The results of the rupture tests are shown in Table 2. Stresses on the brazed specimens were calculated from their cross-section area after brazing.

There is considerable doubt as to the reliability of the two figures marked with the letter D, particularly the V-notch test that ruptured in 77 hr. Generally there is quite a good correlation between reduction of area at fracture and V-notch rupture life for this alloy. Based on the 18.0% reduction of area of the smooth-bar specimen, the notched specimen should have failed in the neighborhood of 1000 hr.

If the results from the unbrazed specimens are compared with those in Table 1(A), it is evident that the smooth bar rupture lives appear to be significantly lower. The rupture ductility and V-notch rupture lives are not believed to be appreciably changed. There are insufficient data to warrant definite conclusions but it is suspected that this loss in life is caused by surface reactions during the brazing cycle. Changes at such exposed surfaces have been observed metallographically. Figures 2*A* and 2*B* are photomicrographs of longitudinal sections cut from fractured smooth-bar rupture specimens. Figure 2*A* is of a specimen machined after being submitted to the brazing cycle. The test results from this specimen were reported in Table 1 (A) (471 hr). Figure 2*B* is of a specimen fully machined prior to passing through the brazing cycle. The test results were reported in Table 2 (203 hr). Note the differences in structure evident at the surfaces of the samples.

These data also show a highly pronounced effect of postbrazing heat treatment on the rupture properties. Resorting to a postbrazing solution heat treatment results in a more attractive combination of properties for most applications. The presence of the brazing compound at the surface was beneficial to the rupture properties. The brazed samples possess better ductility and improved rupture life, both V-notch and smooth bar.

Microstructural examinations of blanks that were surface brazed with the specimens showed that the brazing compound was uniformly deposited to a

**Table 2—Surface-Brazed Specimens**

| *Heat treatments* | *Condition* | *Rupture life, hr* | | *Elongation, %* | *Reduction of area, %* |
|---|---|---|---|---|---|
| | | *V notch* | *Smooth* | | |
| B. C.* + 1325° F—16 hr—air | No braze | 72 | 321 | 2.5 | 3.5 |
| B. C.* + 1325° F—16 hr—air | Brazed | 99 | 415 | 5.0 | 9.0 |
| B. C.* + 1650° F—1 hr—rapid cool + 1325° F—16 hr—air | No braze | 77 (D)† | 203 | 14.7 | 18.0 |
| | Brazed | 4262 | 253 | 13.5 | 24.6 |
| B. C.* + 1800° F—1 hr—rapid cool + 1325° F—16 hr—air | No braze | 744 | 80 (D)† | 9.7 | 15.2 |
| | Brazed | 2214 | 257 | 11.6 | 19.6 |

* B. C., brazing cycle.
† Doubtful results.

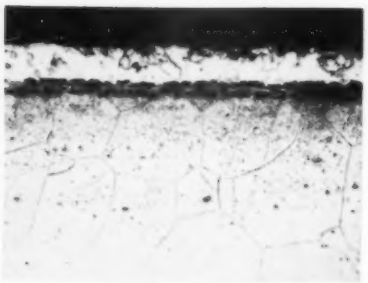
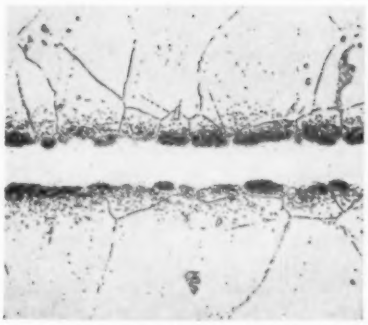
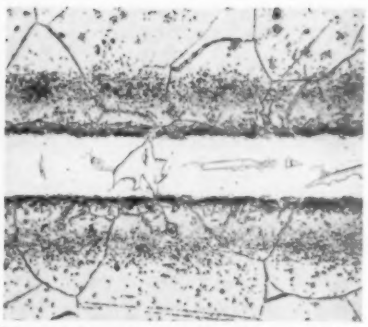


Fig. 3 Microstructure of surface-brazed specimen of A-286 alloy. X 250. (Reduced by one-half upon reproduction)



(A) Joint brazed with an estimated original clearance of less than 0.0001 in. Joint is filled with single-phase material.



(B) Joint brazed with an estimated original clearance of 0.0005 in. Material in joint consists of three distinct phases.

Fig. 4 Effect of brazing clearances on microstructure of butt joints. X 500. (Reduced by one-half upon reproduction)

thickness of 0.001 to 0.0015 in. As would be expected from the high brazing temperature, the grain size was large. A phase foreign to the alloy, presumably a high B compound, was observed to a considerable depth (see Fig. 3). Throughout the matrix this phase extended to a depth of about 0.005 to 0.009 in. and along grain boundaries to a depth of 0.010 to 0.014 in. The samples solution heat treated after brazing appeared to show about the same or slightly greater penetration of this phase indicating that very little, if any, additional diffusion took place at the solution temperatures.

### Brazing Variables and Microstructure

The effects of varying initial brazing clearances upon the microstructure at the brazed joints are shown in Figs. 4*A* and 4*B*. As the clearances are increased, pronounced microstructural differences are observed at the joints. At very small clearances of somewhat less than 0.0003 in., the joint is filled with a homogeneous-appearing single phase. As the original clearances are increased up to about 0.002 in., increasing amounts of two additional constituents are observed at the centers of the joints. These two excess constituents are observed at clearances as small as 0.0003 in. under these conditions of brazing. Figure 4*B* is of a braze made with an original clearance of 0.0005 in. which shows these constituents. The large massive constituent is quite hard and is easily observed in as-polished specimens. The other constituent, which has a mottled appearance, is somewhat softer and is observed only with difficulty in as-polished specimens. The harder constituent is quite easily removed during polishing unless careful procedures are followed. Butt-brazed tensile specimens usually fracture through these constituents. It seems advisable to utilize clearances as small as possible, consistent with good filling, to minimize the amounts of these constituents.

The extreme erosive action of the AMS-4775 brazing alloy upon the base alloy is indicated in Figs. 4*A* and 4*B*. Even with very small clearances and short brazing times, the original interfaces of the base metal are widened markedly. Diffusion of elements from the brazing alloy into the base metal also occurs rapidly as shown by the presence of chains of foreign constituents principally in the grain boundaries of the base metal.

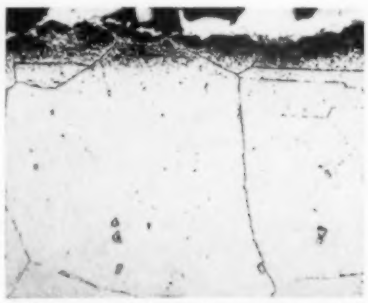
The effect of varying the time at brazing temperatures upon the microstructure are shown in Figs. 5*A* and 5*B*. These are photomicrographs of butt-brazed tensile specimens at the fracture edges. Both of these samples were preheated to 1800° F and brazed at 2100° F utilizing zero clearance. The higher belt speed (Fig. 5*A*) corresponds to a time of $3^3/_4$ min and the slower belt speed (Fig. 5*B*) to a time of 15 min in the high-temperature zone of the furnace. Observe the marked differences in the amounts of foreign phases at the grain boundaries of the base metal. At the comparatively low belt speeds of 20 fph, fractures frequently occurred through the grain boundaries of the base metal, i.e., entire grains were plucked out of the base metal during fracture. A typical example of this is shown in Fig. 6. This mode of failure was not observed at faster belt speeds of 40 and 80 fph.

### Butt-Brazed Specimens

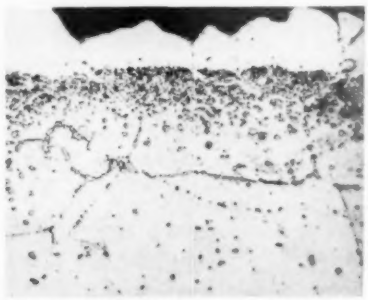
Butt-brazed specimens were prepared by machining blanks, $2^1/_2$ in. over-all length to $^9/_{16}$ in. diam by $1^1/_4$ in. at one end and $^3/_8$ in. diam by $1^1/_4$ in. long at the other. At the end of the $^3/_8$-in. diam section, a 45-deg chamfer was machined to a depth of 0.020 in. Each such blank constituted one-half of a final butt-brazed specimen. Each pair of blanks was provided with a $^3/_8$-in. ID by $^1/_2$-in. OD collar. A $^1/_8$-in. diam hole was drilled into the collar for the braze-metal deposit and a $^1/_{32}$-in. diam hole for gas escape at a diametrically opposite position.

The collars and blanks were brazed after assembly under various conditions of belt speeds and clearances. These were subsequently heat treated at 1650° F—1 hr—oil quench + 1325° F—16 hr—air cool in air atmosphere furnaces and machined to standard tensile and smooth-bar rupture specimens.

Of the conditions investigated, the best joints were obtained with a preheat



(A) Belt speed—80 fph ($3^3/_4$ min brazing time). Little diffusion of brazing alloy into base metal is apparent.



(B) Belt speed—20 fph (15 min brazing time). Brazing alloy has diffused comparatively large distances into base metal and has formed semi-continuous chains of precipitate at grain boundaries.

Fig. 5 Effect of belt speed on microstructure of butt joints. X 500. (Reduced by one-half upon reproduction)

of 1700° F, a belt speed of 40 fph and a clearance of 0.0015 in. This belt speed corresponds to a time of about 7½ min in the high-temperature zone of the furnace. Joints brazed at lower belt speeds or smaller clearances were generally incompletely filled. It was felt that the poor filling was attributable to inadequate design of the specimens. Because of the wide melting range and alloying tendency of this brazing alloy, it is desirable that the region in which the brazing alloy is applied be the last part of the joint to be heated to the brazing temperature. This desirable feature was not met in the joint design used.

The properties obtained on the butt-brazed specimens are shown in Table 3 (A) and (B). The conditions under which the tests were made were identical to those described previously.

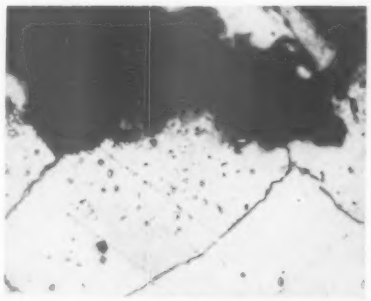


**Fig. 6 Portion of fracture of butt-brazed joint that has proceeded through grain boundaries of the base metal**

Belt speed was 20 fph (15 min brazing time). X 500. (Reduced by one-half upon reproduction.)

**Table 3—Butt-Brazed Specimens**

(A) Stress rupture tests

| *Temperature, ° F* | *Stress, psi* | *Rupture life, hr* | *Elongation, %* | *Reduction of area, %* |
|---|---|---|---|---|
| 1200 | 60,000 | 3½ | 0.9 | 1.5 |
| 1200 | 50,000 | 82 | 0.0 | 0.0 |

(B) Short-time tensile tests

| *Temperature, ° F* | *0.02% offset yield strength, psi* | *0.1% offset yield strength, psi* | *0.2% offset yield strength, psi* | *Ultimate tensile strength, psi* | *Elongation, %* | *Reduction of area, %* |
|---|---|---|---|---|---|---|
| 78 | 60,700 | 89,200 | .. | 90,200 | 0.1 | 0.0 |
| 1200 | 66,100 | 80,200 | 85,000 | 95,800 | 0.9 | 3.5 |
| 1200 | 61,700 | 84,100 | 89,200 | 92,200 | 1.0 | 1.6 |
| 1300 | 72,000 | 80,400 | .. | 81,100 | 0.1 | 0.0 |

The rupture strengths of the butt-brazed samples are below the scatter band for A-286 but are reasonably high. Because the brazed joints are considerably weaker than the base metal, it is reasonable to expect extremely low ductility when measured over a gage length (about 0.8 in.) several hundred times the width of the joint. This is equally applicable to the ductility values reported for the tensile specimens. The offset yield strengths were measured with a 2-in. extensometer so the values reported in Table 3 (B) would be measures of the A-286 alloy strength. Except for the room-temperature test, the tensile strengths are about the same as those reported by Peaslee and Boam for S-590 Alloy brazed with an alloy covered by AMS-4775 under far different brazing conditions. Peaslee and Boam, however, obtained much higher values of ductility. This may be because they were dealing with a weaker base metal. The rupture properties cannot be directly compared with those obtained by Peaslee and Boam on butt-brazed S-590 at 1500° F but it appears as though they would be comparable at the same temperature.

### Double-Lap Shear Specimens

Double-lap shear specimens were prepared from a 0.065-in. thick sheet of A-286 alloy. The sheet was sheared to 1-in. wide by 6-in. long pieces. Three such pieces were assembled to form each test specimen, spot welded with zero clearance to an overlap of about 0.070 in., and brazed. The samples were preheated to 1400° F and brazed at a belt speed of 80 fph which corresponds to a time of about 3¾ min in the high-temperature zone of the furnace.

Some of these samples were solutioned for 15 min at 1650° F and some for 15

**Table 4—Shear Strengths of AMS-4775 Joints**

| *Heat treatment* | *Temperature, ° F* | *Shear stress at fracture, psi* |
|---|---|---|
| 1325° F–16 hr—air | 75 | 36,300 |
| | 75 | 38,100* |
| | 75 | 49,100 |
| | 1200 | 27,400 |
| | 1300 | 29,700 |
| 1800° F—¼ hr—fast cool + 1325°F—16 hr—air | 75 | 43,200 |
| | 1200 | 31,700 |
| | 1300 | 34,500 |
| | 1300 | 31,200 |
| 1650° F—¼ hr—fast cool + 1325° F—16 hr—air | 75 | 45,700 |
| | 1200 | 35,050 |
| | 1200 | 33,000 |
| | 1300 | 31,600 |
| | 1300 | 34,900 |

* Joint not completely filled—shear strength calculated from filled area.

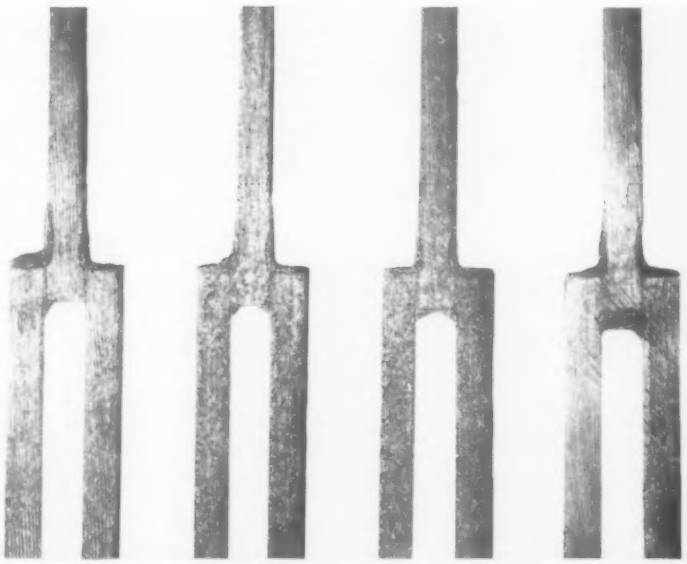


**Fig. 7 Photomacrograph of double-lap brazed specimens showing varying amounts of overfill**

Observe the highly erosive effect of the brazing alloy upon the base metal. X 3.5.

min at 1800° F in a dry hydrogen atmosphere. The remaining few were not solution heat treated after brazing. All were later aged at 1325° F for 16 hr in air atmosphere furnaces. The appearance of these samples after a light macroetch is shown in Fig. 7. Observe the large amount of erosion or alloying which occurred in the areas where the brazing-alloy powder was applied.

The specimens were machined to a 0.375-in. wide by 2-in. reduced section. The excess brazing alloy was removed by filing. All specimens were pulled to fracture at a head speed of 0.05 ipm. The resulting shear stresses were calculated from the joint areas measured after fracture. The results of these tests are shown in Table 4.

Peaslee and Boam obtained shear strengths of AMS-4775 when used to join S-590. Their shear specimens were of the tongue and slot double-shear type. They obtained values of about 42,000 psi at room temperature, about 30,500 psi at 1200° F and about 29,500 psi at 1300° F. The values obtained in this investigation on the brazed sheet are comparable or slightly higher. A part of this difference may be very well due to differences in the design of specimens.

## Conclusions

A technique has been established which makes it possible to obtain consistently sound high-strength brazed joints in a high-temperature alloy containing titanium which does not require plating of the surfaces to be brazed. The success of this technique is based on the tentative theory that reactive elements in a surface layer can be preferentially oxidized by a suitable heat treatment. The oxide is then removed chemically. The newly exposed surfaces possess satisfactory characteristics for brazing in dry hydrogen atmospheres. A short brazing cycle appears necessary in order to avoid further diffusion of the reactive elements from the interior into the surface.

The brazing heat-treatment cycle deleteriously affects the room and elevated temperature properties of A-286 alloy. The reduction in properties however, can be almost completely recovered by using a postbrazing solution heat treatment.

A Ni-Cr-B brazing alloy produces pronounced microstructural changes in the A-286 alloy by diffusion. The presence of this diffused zone at the surfaces of the alloy appears to result in a slight improvement of the base metal's rupture properties.

An indication of the short-time tensile strengths and rupture properties of butt-brazed joints and short-time shear strengths of lapped joints has been obtained. These properties are satisfactory for high temperature performance. In general they compare well with previously published results and should be useful from a design standpoint.

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2. Rose, A. S., and Lewis, W. N., "High-Temperature Alloy Brazing of Thin Materials for Jet Engines," *Ibid.*, **34** (1), 30–39 (1955).
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# QUALITY CONTROL OF STEELS FOR WELDED PENSTOCKS

*(Continued from page 365-s)*

under load, and so that there is no danger of electrochemical corrosion. Second, the weld should have as uniform microstructure as possible. Finally, there should be no fisheyes or other porosity in the weld metal.

**Table 4—Comparison of Three Types of Tests on Seven Class A Steels, As-Received**

| | *Steel Kuntze test** | | | *Kommerell test* | | | *Sharp notch-impact value, mkg/cm²* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Reduction of area, %, in impact tension* | | | *Bend angle, deg, at fracture* | *Type of fracture* | *Thickness, in.* | | | |
| | *Notched* | *Unnotched* | *Ratio* | | | | *+20° C* | *0° C* | *−20° C* |
| 1 | 10.5 | 15.8 | 0.66 | 130 | Ductile | 0.43 | 3.6 | 1.1 | 0.7 |
| 2 | 11.2 | 25.5 | 0.46 | 170 | Ductile | 0.87 | 6.1 | 1.3 | 0.6 |
| 3 | 16.5 | 19.9 | 0.83 | 152 | Ductile | 1.18 | 12.5 | 1.3 | 4.0 |
| 4 | 7.8 | 23.1 | 0.34 | 130 | Ductile | 1.18 | 4.8 | 9.5 | 1.0 |
| 5 | 4.3 | 21.3 | 0.22 | 113 | Ductile | 0.71 | 1.6 | 0.7 | 0.4 |
| 6 | 4.5 | 19.4 | 0.23 | 140 | Brittle | 0.67 | 4.9 | 1.7 | 0.9 |
| 7 | 12.8 | 10.2 | 1.1 | 95 | Brittle | 0.51 | 16.2 | 6.1 | 3.0 |

* An unnotched Kuntze reduction of area of 22% is regarded as minimum.

# PROBLEMS ASSOCIATED WITH THE WELDING OF T-1 MATERIAL

*Some of the problems that have been encountered in field welding T-1 steel are described and the tests undertaken to find a solution to these problems are discussed*

BY PERRY C. ARNOLD

## Introduction

Several large pressure vessels have been built using T-1 material. W. D. Doty[1] has given the properties and characteristics of T-1. L. P. Zick[2] presented the design of welded pressure vessels using quenched and tempered steel, and L. C. Bibber[3] has described the suitability of this material for pressure vessel construction. The ASME Unfired Pressure Vessel Code, Case 1204-3, approved its use with certain limitations.

The purpose of this paper is to describe some of the problems that have been encountered in field welding T-1 and to acquaint industry and the code regulatory bodies with the solutions of these problems. It should be clearly understood at the very beginning that to date no trouble has been encountered with the T-1 material, but only with the weld metal. The trouble appeared in the form of transverse cracking in weldments made in the field under conditions of high restraint and unfavorable weather conditions.

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Presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

Engineers and metallurgists have known for many years that excellent toughness can be secured from quenched and tempered material. They have been reluctant to use this material extensively due to the difficulties encountered when trying to join the sections by welding. With several low-hydrogen electrodes that are on the market today, these tough materials can be readily welded if the metallurgical properties are given due consideration and the correct welding procedure is used. Much of the story of this paper concerns this very important welding procedure.

## Difficulties Encountered

Figure 1 is a picture of two 110 ft 6 in. diam Hortonspheres made of 0.73 thickness T-1 material that were erected in Tokyo, Japan. The design stress was $^{4}/_{10}$ the yield multiplied by a 90% joint factor, or 32,400 psi. The working pressure is 71.1 psi and the vessels were tested pneumatically at 88.9 psi. Each of these vessels store approximately 3,500,000 cu ft of manufactured gas. They were fabricated here in the States and field erected in Tokyo by the Ishikawajima Heavy Industries under the supervision of the author's company.

Figure 2 shows some of the plates being ground assembled into large sections. Since a-c welding machines were to be used, an E12016 nickel, moly, vanadium electrode was chosen. The welding procedure was qualified in accordance with Section IX and Case 1204 of the ASME Code without any difficulty. From previous shop experience and results of tests made by the U. S. Steel Corp., preheat was thought to be unnecessary. The electrodes were stored in a drying oven at 300 to 400° F. During the ground welding of these sections, an occasional transverse crack was found by radiographic examination. Most of the cracks were contained within the weld metal but occasionally a few ran into the heat-affected zone. This cracking was eliminated by peening the welds sufficiently to lower the longitudinal shrinkage stresses which were pulling the weld metal in two.

Figure 3 shows these ground sections being assembled into the final structure. As erection progressed, the closing joints were welded and radiographed. In the first thirty feet of circumferential joint that was welded between the equator and bottom plates, over sixty transverse cracks were found. Many of the cracks were visible to the eye.

Fig. 1 Two 110-ft 6-in. diam T-1 spheres erected in Tokyo, Japan

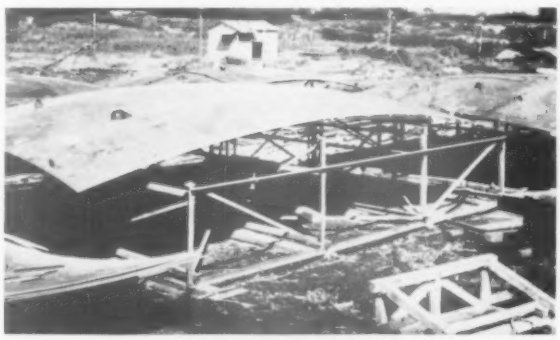

Fig. 2 Ground assembly of T-1 sphere plates

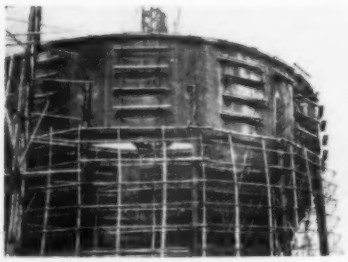

Fig. 3 Assembly of T-1 sphere

while others were visible only in the radiographs.

**Reproducing Difficulties in Laboratory**

Directly after encountering this transverse weld-metal cracking in the ground assemblies in Tokyo, a test program was started in the laboratory here in the States to evaluate this condition. Small test plates of a size normally used for procedure qualifications were again welded in all positions without preheat and with 75° F interpass temperature. No cracks could be manufactured in this manner. Since the cracking problem in Tokyo did not become serious until the first circumferential joint was welded, it was felt that the high restraint from joining large sections together was a contributing factor. A test was therefore designed that would provide high angular and lateral restraint.

Figure 4 gives the details of the first method used in providing high restraint. This method provides angular, lateral and end restraint sufficient to cause the transverse cracking to occur on laboratory size plates. Figure 5 shows another test method that was designed to provide the necessary restraint. This method proved more satisfactory than the first because of the easier way of attaching and removing the test plates. Both methods give reproducible results which one must have before it is possible to start to solve the problem.

Figure 6 shows a radiograph taken from one of the test plates that was welded in a restrained jig, using the E12016 electrode. This plate was welded in the horizontal position, that is, the plate itself was kept in a vertical plane with the axis of the weld horizontal. This position was chosen as this is where maximum cracking was experienced in Tokyo. The test plates were welded without preheat with an interpass temperature of 75° F and with the electrodes in the as-received condition but stored continuously in a drying oven at 300 to 400° F except at time of use.

Figure 7 shows the test plate which was sectioned through the center of the weld. The longitudinal surfaces were macroetched and are also shown. Please note that not only are the transverse cracks that were shown in the X-ray

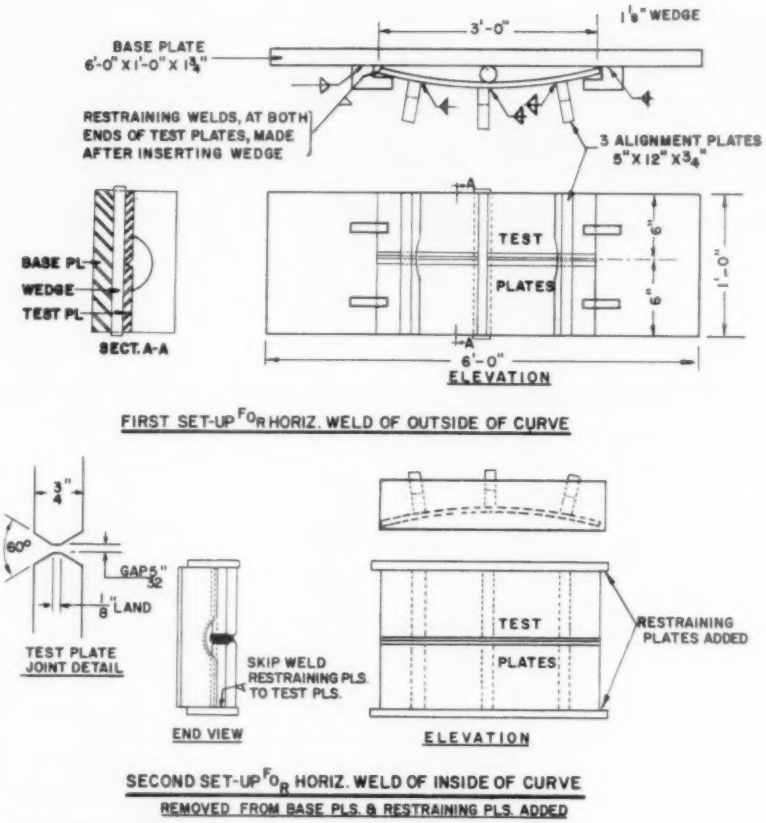


Fig. 4 First method used to provide high restraint

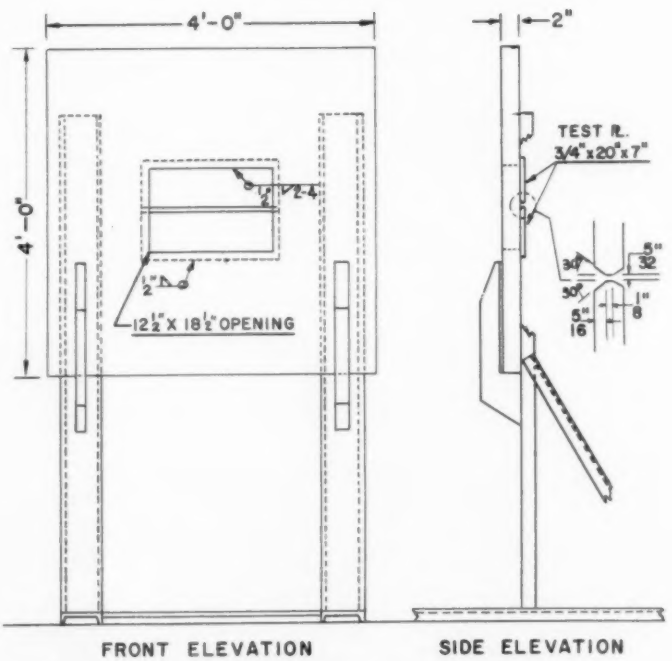


Fig. 5 Second method used to provide high restraint

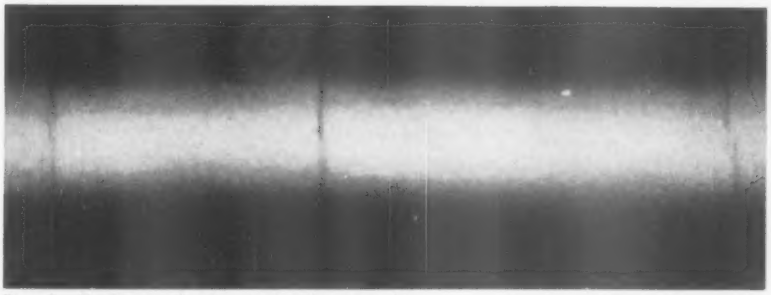

Fig. 6 Radiograph of restrained-test weld

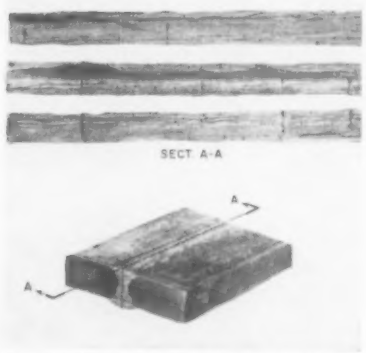


Fig. 7 Test plate sectioned and longitudinal surfaces macroetched

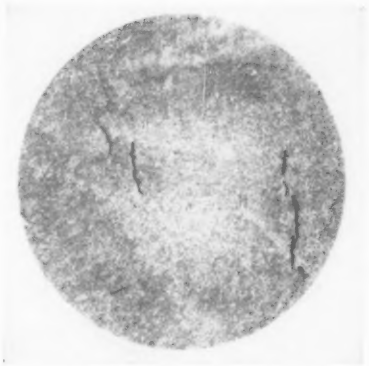

Fig. 8 Photomicrograph of fissures

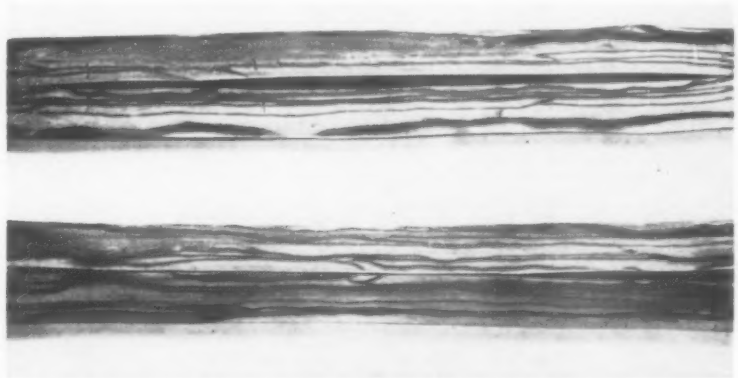

Fig. 9 Longitudinal weld sections, welded with rebaked electrodes but no preheat

present; but also many small fissures or microcracks. It is felt that the large transverse cracks are extensions of the microfissures. These microfissures cannot be found by radiography. They can also be present in a weld without the accompanying visible transverse cracks. More will be said about this later when the explosion bulge tests are described. Figure 8 is a photomicrograph of these fissures. It was found that the fissures always had their origin and were normally contained in the heat-affected zone in the weld metal resulting when a weld bead was placed on top of another weld bead.

**Elimination of Difficulties**

After learning how to produce these cracks at will, other electrodes in the E120, E110, E100 and E90 series were evaluated. With only one exception, all of the various weld metals showed the microfissuring to some extent. The higher the tensile strength, the more pronounced was the microfissuring and cracking when using the high restraint, no preheat and 75° F interpass temperature. The one exception was an E12015 dipped electrode which was found to contain only 0.03% moisture in the coating. This was extremely low and about 1/7 the 0.20% normally contained in the other electrodes. Upon contacting the electrode manufacturer, it was found that a dipped electrode could be baked out to a much lower moisture content than could an extruded one. The reason given was that when the electrode is made by the extrusion process, a slipping agent is added which contains a large amount of water of crystallization. If the electrode is baked at a high enough temperature or for a long-enough time to remove this moisture, the coating becomes so brittle that it will not stand up under shipping and handling conditions.

The low-moisture content was the first clue to a solution of the microfissuring and cracking. Some of the E12016 electrodes were secured from Tokyo

Table 1—Typical Chemistry and Physical Properties of Deposited Weld Metal as Welded

| | | *C* | *Mn* | *Si* | *Ni* | *Mo* | *V* | *Yield* | *Ultimate* | *Elongation* | *Reduction of Area* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Horizontal | | | | | | |
| 1-12 | 10016 | 0.06 | 0.91 | 0.42 | 1.78 | 0.34 | 0.17 | 100,500 | 107,000 | 21 | 57 |
| 2-AA | 10016 | 0.06 | 1.77 | 0.70 | .. | 0.46 | .. | 98,800 | 106,500 | 25 | 61 |
| 3-17 | 12016 | 0.06 | 0.97 | 0.36 | 2.00 | 0.61 | 0.16 | 123,500 | 128,500 | 15 | 46 |
| 4-AA | 12016 | 0.06 | 1.00 | 0.40 | 1.90 | 0.90 | 0.20 | 115,000 | 126,000 | 21 | 53 |
| 5-A | 12015 | 0.05 | 0.94 | 0.45 | 1.75 | 0.76 | 0.25 | 123,500 | 129,000 | 17 | 45 |
| | | | | | Flatdown | | | | | | |
| 1-12 | 10016 | | | | | | | 92,000 | 96,000 | 24 | 55 |
| 2-AA | 10016 | | | | | | | 91,500 | 101,500 | 28 | 67 |
| 3-17 | 12016 | | | | | | | 105,000 | 116,500 | 19 | 46 |
| 4-AA | 12016 | | | | | | | 110,000 | 121,000 | 22 | 60 |
| 5-A | 12015 | | | | | | | 113,000 | 124,000 | 20 | 57 |

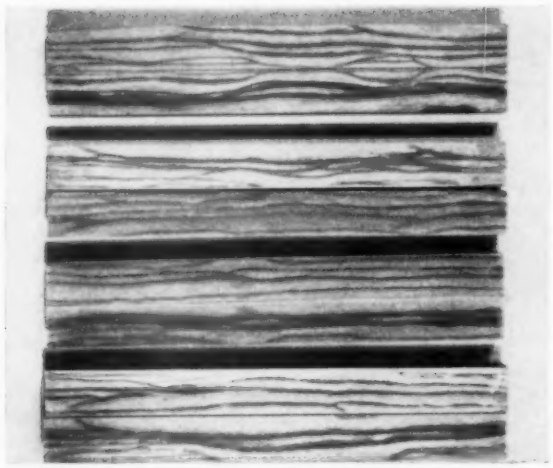

Fig. 10 Longitudinal weld sections, welded with rebaked electrodes and preheated 200 to 300° F

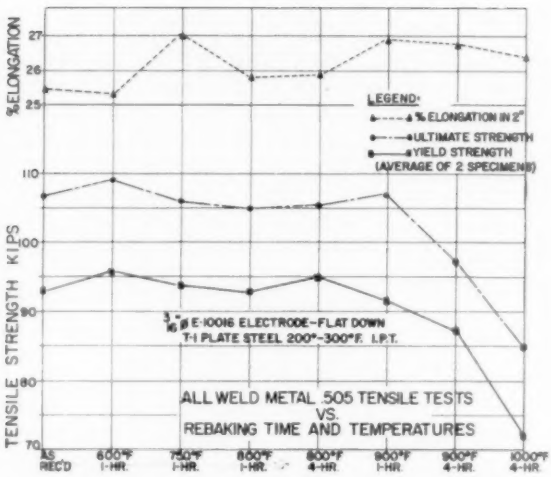


Fig. 11 Tensile and elongation properties of all-weld-metal 0.505 specimens vs. rebaking time and temperature of electrodes

and rebaked at 850° F for 4 hr and found usable with a moisture content of approximately 0.10%. Figure 9 shows some weld specimens, after being sectioned longitudinally and etched, made with the rebaked electrode, under high restraint, 75° F interpass temperature and no preheat. Only a few microfissures were evident. Since the rebaking of the electrode did not completely solve the fissuring tendency, other procedure variables had to be evaluated.

The next variable added was to use a moderate preheat along with the rebaked electrodes. Figure 10 shows the sectioned and etched specimens from a restrained plate made in the horizontal position using rebaked electrodes and a preheat and interpass temperature of between 200 and 300° F. The microfissuring completely disappeared. Other tests proved that 150° F was the minimum preheat that could be used and still eliminate all fissuring.

Many additional tests were made in all positions to prove that the use of the rebaked electrodes and a preheat of over 150° F completely solved the fissuring and cracking of the weld metal. These additional tests showed very satisfactory results. This procedure was then applied to the welding of the spheres in Tokyo and the cracking of the weld metal was completely eliminated.

In the interpretation of the physical results of the many tests that were made, some very interesting facts were noted. This will be of interest to both the welding engineer and the electrode manufacturer. Table 1 shows the chemical and physical properties of the weld metal from five different electrodes. Please note that in the flatdown position where larger electrodes and higher heat inputs are used, the tensile strength of the weld metal is very close to the AWS classification. In the horizontal position where smaller electrodes and less heat input is used, the tensile strength of the weld metal is from 5000 to 12,000 psi higher than from the flatdown position. This higher strength from a faster quench rate in the horizontal position undoubtedly contributed to the more severe cracking tendency.

Another interesting and important fact observed was that the tensile strength of the deposited weld metal from the rebaked electrodes could be greatly altered through the temperature and time bake cycle. Figure 11 shows a graph of the tensile and elongation properties of all-weld-metal 0.505 specimens vs. the time and temperature rebaking cycles. This clearly shows that these low-hydrogen electrodes that have most of the alloys in the coatings should definitely never be rebaked at a temperature higher than 900° F or for a period longer than 1 hr at this temperature. Moisture determination results from these rebaked electrodes indicate that as much moisture is removed from the electrodes at 500° F for 24 hr as at 850° F for 1 hr.

## Additional Welding Considerations

Since T-1 steel is a quenched and tempered material, some consideration must be given to the welding procedure used so that it will not impair the tensile and toughness properties of the steel. If too high a preheat is used some portion of the heat-affected zone may be tempered sufficiently to lower the tensile strength. There is also the possibility that the impact strength of this zone might be impaired.

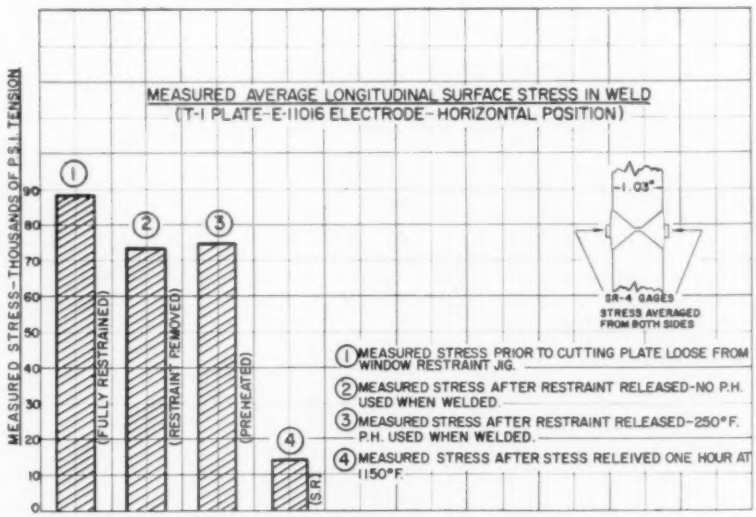
MEASURED AVERAGE LONGITUDINAL SURFACE STRESS IN WELD
(T-1 PLATE-E-11016 ELECTRODE-HORIZONTAL POSITION)
MEASURED STRESS-THOUSANDS OF P.S.I. TENSION
(FULLY RESTRAINED)
(RESTRAINT REMOVED)
(PREHEATED)
(S.R.)
1.03"
SR-4 GAGES
STRESS AVERAGED FROM BOTH SIDES
(1) MEASURED STRESS PRIOR TO CUTTING PLATE LOOSE FROM WINDOW RESTRAINT JIG.
(2) MEASURED STRESS AFTER RESTRAINT RELEASED-NO P.H. USED WHEN WELDED.
(3) MEASURED STRESS AFTER RESTRAINT RELEASED-250°F. P.H. USED WHEN WELDED.
(4) MEASURED STRESS AFTER STESS RELEIVED ONE HOUR AT 1150°F.

Fig. 12 Results of strain-gage measurements on restrained T-1 test plates

Several test plates of 1-in. thickness were welded using a preheat and interpass temperature as high as 550° F. Reduced-section tensile coupons taken transversely to the joint did not show any drop in the tensile strength. Charpy-impact specimens, both "V" and keyhole, taken from the heat-affected zone, failed to show any impairment. It is quite possible and likely that there may be some impairment of the notch toughness of the heat-affected zone that would not be shown by the standard Charpy-impact tests. It must be realized that it is virtually impossible to locate the notch of the impact specimen in the microstructure of the heat-affected zone that may have been affected.

Nippes and Sibley,[4] in their work with synthetically reproduced microstructures in T-1 material, have shown that some impairment of the notch toughness can occur from the effect of various peak temperatures and cooling rates. It should also be clearly understood that a certain preheat on heavy material, such as described in this paper, might not disturb the cooling rate to any great extent but the same preheat on light material might greatly alter the microstructure in the heat-affected zone. In other words, a good policy to follow is to use preheat only when required to prohibit weld metal cracking, and then use it moderately.

In evaluating the necessity or advantages of using preheat, several interesting tests were performed. Several restrained test plates were welded with the E10016 low-hydrogen electrodes which had been subjected to a sufficiently high relative humidity to cause them to pick up moisture to as high as 0.35%. This is almost double the moisture content normally found in most of the high-strength electrodes as received from the supplier. With a preheat and interpass temperature of 250° F during welding, no visible transverse cracking occurred. Several rebaked electrodes were exposed to a relative humidity of 67% at a temperature of 75° F for different periods of time. It was found that in the first thirty minutes of exposure the electrodes picked up about 0.11% moisture. Therefore it is felt that preheat is good insurance against microfissuring when there is the possibility of the electrodes picking up moisture from the atmosphere.

It is also felt that hydrogen from the moisture in the electrode coating causes the microfissuring. Vaughan and DeMorton[5] have covered quite well the subject of hydrogen embrittlement of steel. It is an established fact that the addition of heat will drive off this hydrogen rapidly. This is undoubtedly another advantage of using preheat. Most welding engineers agree that preheat aids in two other ways in preventing the microcracking. It slows down the quench rate of the weld metal, thus making it more ductile, and at the same time tends to lower the residual welding stresses.

Figure 12 shows the results, in a graphic form, of some strain gage measurements on T-1 restrained test plates. Only the longitudinal stresses are shown for the various conditions of restraint, preheat and stress relief. These are average stresses from the two sides of a weld and are surface stresses only. These 1-in. thick plates were welded in the horizontal position under high restraint using an E11016 electrode. Note that when the test plate was cut loose from the restraining jig, the stresses were lowered approximately 15,000 psi. Also note that preheat did not seem to have much effect in lowering the residual stresses under the high-restraint condition. It is also interesting to see that after stress relieving the test plate for one hour at 1150° F, a residual stress of approximately 15,000 psi still remains in the surface of the weld.

The ASME Code Case 1204–3 requires that any pressure vessels built of T-1 material of over 0.58 in. in thickness shall be stress relieved. This automatically eliminates the use of most of the E12015–16 electrodes that contain vanadium. When this type of electrode is used and the weld metal is stress relieved the heat treatment apparently produces an embrittlement which greatly lowers the impact strength. In the search for a high-strength electrode that would give weld metal that would stand the stress-relieving treatment and not become embrittled, a good E11016 electrode, with iron powder added, was found. The as-deposited weld metal from this electrode contains approximately 1.75% nickel, 0.30% chromium, 1.40% manganese, 0.45% molybdenum, 0.35% silicon. Procedure tests were made in all positions using this electrode on six feet square T-1 plates of $1^1/_2$-in. thickness. The large plates were highly restrained with long transverse T-1 stiffeners which were left in place until the entire weld was completed. Rebaked electrodes and preheat of 250° F were used on these test plates. Tensile, bend and impact tests were made in both the as-welded and stress-relieved conditions. The transverse reduced-section tensile specimens mostly failed in the plate at close to 120,000 psi. The elongation from free and guided bends was exceptionally good and the impact strength at −50° F was very satisfactory.

### Navy Explosion-Bulge Tests

This relatively-new E11016 electrode more than met the qualification procedures as required by Section IX of the ASME Code. However, there were still several welding variables that could not be evaluated with these tests. Unrestrained test plates welded with most any of the high-strength electrodes would satisfactorily pass the code

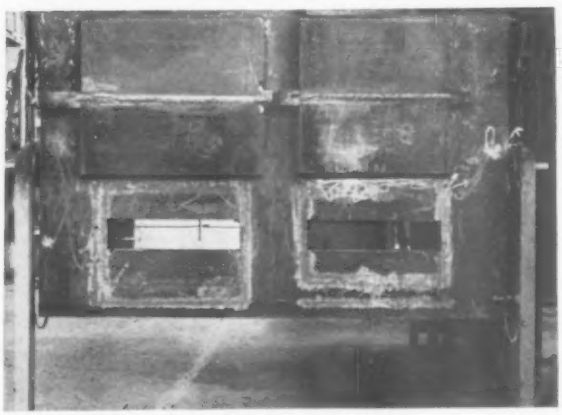

Fig. 13 Front side of window restraint jig

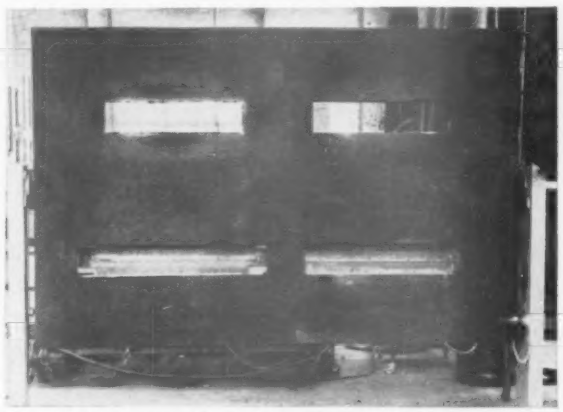

Fig. 14 Back side of window restraint jig

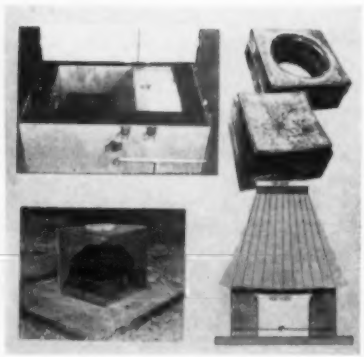

Fig. 15 Navy setup used in explosion tests, after Puzak and Pellini[6]

requirements. How would the weldments perform under shock or plastic loading? What effect did the restraint, moisture, microcracks and preheat have on the performance of the weldment? It was felt that perhaps the Navy explosion-bulge test might evaluate these variables, particularly the effect of the microfissures and small cracks that might be present in the weld that could not be detected by radiographic examination.

The Navy Department was acquainted with these problems and unanswered questions. It appeared that the well-known explosion-bulge test might be the only test that would evaluate these variables. A cooperative test program was proposed to the Bureau of Ships for this additional evaluation. The tests were conducted by the Naval Research Laboratory as part of a continuing Bureau of Ships program for investigating the factors which control the performance of welded alloy steels. The Naval Research Laboratory was furnished test plates welded under various conditions and using this new electrode. The assistance and cooperation of the Bureau of Ships and the Naval Research Laboratory were greatly appreciated. The following report and interpretations of the tests are those of the author and do not necessarily reflect the approval of the Bureau of Ships or the Naval Research Laboratory. Figures 13 and 14 show the plates being welded in the window restraint jig.

Figure 15 shows the Navy setup used in the explosion tests and as shown by Puzak and Pellini[6] in their recent article on notch toughness. All explosion test plates were taken from scrap ends cut from the material that was furnished for the second set of two spheres that were erected in Tokyo. All plates were 1.03 in. in thickness by 20 in. square and welded with the new E11016 electrode in the horizontal position. All plates were left in the as-welded condition. All plates except ET-11 and ET-12 were welded with the axis of the weld made parallel to the principal rolling direction of the plates. All plates are of firebox quality with maximum cross rolling. All welds were ground smooth for X-ray purpose but were not ground flush.

Figure 16 shows the first four plates that were subjected to a various number of explosion charges of 7 lb of pentolite at a stand-off distance of 15 in. while at a temperature of 30° F. ET-1 was welded with electrodes as received, approximately 0.20% moisture, with no restraint, no preheat and 75° F interpass temperature. ET-2 was welded with electrodes as received, with high restraint, no preheat and 75° F interpass temperature. ET-3 was welded with electrodes rebaked at 850° F for 1 hr, approximately 0.10% moisture, with high restraint, no preheat and 75° F interpass temperature. ET-4 was welded with rebaked electrodes, with high restraint, and with a preheat and interpass temperature of 250° F.

Test plate ET-1 contained a few microfissures. Plate ET-2 contained many more because of being welded in the highly-restrained condition. Both test plates were found to be radiographically sound. After two explosions, ET-1 showed two small transverse cracks in the weld metal. Plate ET-2 showed thirteen transverse cracks ranging from small pulled places not quite to the surface to an open one as long as $^3/_4$ in. All cracks were entirely within the weld metal and undoubtedly were the microfissures coming to the surface. Test plates ET-3 and ET-4 which did not contain microfissures due to the welding procedure used, satisfactorily passed two explosions without any sign of failure.

All four test plates were submitted to a third explosion while at 30° F. A third transverse crack opened up in the weld of plate ET-1. The total length of the crack was $1^1/_4$ in. and extended a slight distance into the plate material. In test plate ET-2 one of the previously noted transverse cracks near the center of the test plate increased in size after the third explosion. The crack progressed into the plate on both sides of the weld, made right angle turns and stopped with a total length of tear of approximately three inches.

Test plate ET-3 failed under the third explosion by cracking open for the entire length of the bulge, right adjacent to the heat-affected zone. This is the plate that was welded using high restraint and rebaked electrodes, but no preheat, and an interpass temperature of 75° F. No transverse or longitudinal cracks were apparent in the weld metal.

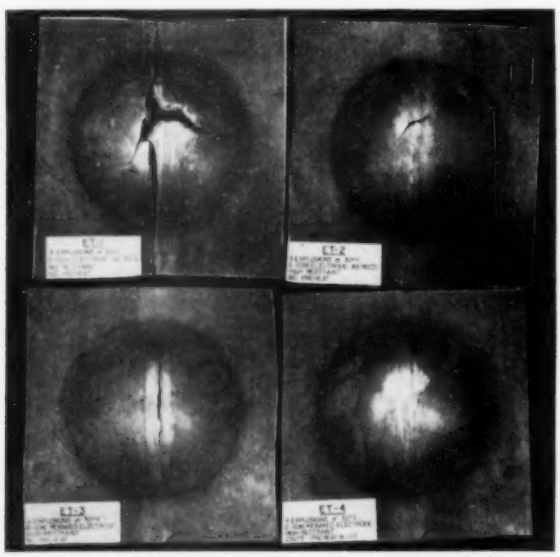

Fig. 16 Welded T-1 plates explosion tested at 30° F

Fig. 17 Welded T-1 plates explosion tested at 0° F

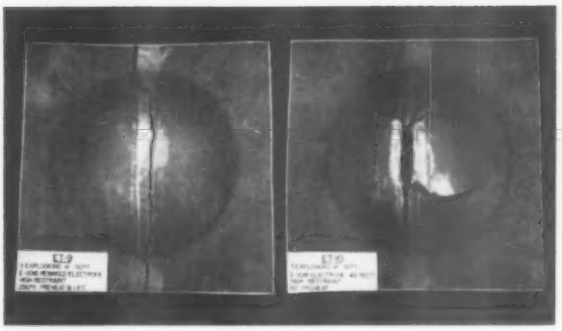

Fig. 18 Welded T-1 test plates explosion tested at −50° F. Axis of weld parallel to principal rolling direction

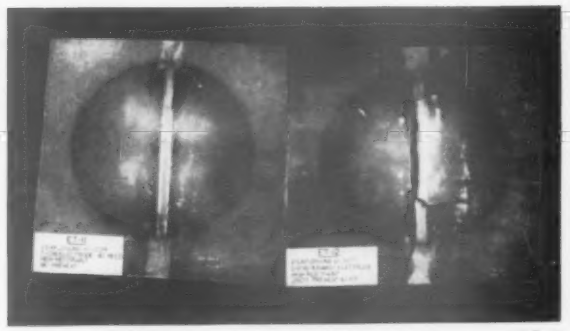

Fig. 19 Welded T-1 plates explosion tested at −50° F. Axis of weld perpendicular to principal rolling direction

Test plate ET-4 which was welded using high restraint, rebaked electrodes and preheat, satisfactorily withstood the third explosion without any signs of failure either in the weld metal or plate material. Test plates ET-1 and ET-4 were submitted to a fourth explosion. ET-1 opened up both transversely and longitudinally to the welds. ET-4 withstood the fourth explosion with no sign of weld metal or plate failure. Plate ET-4 was plastically strained or deformed to a bulge height of approximately 4 in. The reduction in thickness of the plate near the center of the bulge was approximately 22%.

#### Explosion Tests at 0° F

In order to further evaluate the effect of the various welding variables, four additional test plates were welded and tested at 0° F. The same plate material was used along with the same E11016 electrode and welding procedure. Figure 17 shows the second set of plates after the explosion tests. ET-5 was welded using the same procedure as followed for ET-1. ET-6 was made similar to ET-2, ET-7 same as ET-3, and ET-8 duplicated ET-4. Summarizing this procedure again briefly for clarification, ET-5 was welded with no restraint, with electrodes as received (0.20% moisture) with no preheat and an interpass temperature of 75° F. ET-6 was welded using the same procedure as for ET-5 except high restraint was used. ET-7 was welded with high restraint, rebaked electrodes (0.10% moisture), no preheat and an interpass temperature of 75° F. ET-8 was welded using high restraint, rebaked electrodes, and a preheat and interpass temperature of 250° F.

After submitting each test plate to a 7-lb charge of pentolite at a stand-off distance of 15 in., no cracks were observed. After a second explosion the following was observed:

1. Test plate ET-5 showed one transverse crack in the weld near the center of the plate. Another transverse pulled place in the weld was present, indicating that a microfissure was trying to reach the surface. Two short longitudinal cracks were present in the heat-affected zone.

2. Test plate ET-6 split into two pieces after the second explosion. The crack followed the heat-affected zone from one end of the plate to the other. This was a shear-type fracture, not a brittle type. Numerous transverse pulled places were present in the weld, indicating that the microfissures were trying to come to the surface but didn't quite make it.

3. Test plate ET-7 showed one longitudinal crack about one inch long in the heat-affected zone. The weld metal appeared very sound and free of any tears or cracks.

4. Test plate ET-8 showed two longitudinal cracks of two inch and one-half inch length respectively in the heat-affected zone. Again the weld metal appeared very sound and free of any tears or cracks.

Test plates ET-5 and ET-8 were given a third explosion and failed as shown in Fig. 17. Note that in ET-5 one of the transverse cracks that occurred on the second explosion extended to 2 in. in length and that longitudinal cracks in the heat-affected zones opened up for 6- and 12-in. lengths. Plate ET-8 failed in the heat-affected zone for its entire length.

Test plate ET-7 was given explosions number three and four before the crack in the heat-affected zone extended to within 2 in. of the end of the plate. The reduction of thickness near the center of the plate was approximately 15%.

It is very interesting to note that the tests at both 30° and 0° F show that when the weld is sound and free of microcracks, failure will occur principally in the heat-affected zone. However, when the weld contains undersurface defects, the failure may occur either along the heat-affected zone or at right angles to the weld. It is thought that the transverse failures occur if and when a defect is present close to the surface of the weld.

#### Explosion Tests at −50° F

In order to further evaluate the welding procedures, toughness properties of the plate, heat-affected zone and weld metal, four additional plates were tested by the explosion-bulge method at −50° F. The same E11016 electrode was used and all plates were welded in the horizontal position under high restraint. Since some of the previous tests had shown an indication of directional properties of the plate material, two test plates were welded with the axis of the weld parallel to the principal rolling direction, while the other two were welded with the axis of the weld perpendicular to the principal rolling direction.

Figure 18 shows plates ET-9 and ET-10 after testing. Both were made with the axis of the weld parallel to the principal rolling direction. ET-9 was made using rebaked electrodes and a preheat and interpass temperature of 250° F. ET-10 was made using electrodes as received, no preheat and an interpass temperature of 75° F.

Test plate ET-9 showed no visible surface failures after two explosions but separated into two pieces on the third explosion. The separation line was mostly along the heat-affected zone down one side of the weld. The separation did cross the weld at a right angle at one point and then made another right-angle turn again in the plate material and thence on parallel to the weld to the end of the plate. Several other cracks opened up along the heat-affected zone. The weld metal showed no signs of failure except where the separation crossed it transversely.

Test plate ET-10, which contained numerous microfissures in the weld metal, showed three visible weld metal cracks after the second explosion at −50° F. Note that cracks opened up in both the longitudinal and transverse direction after the third explosion. Again, the defects in the weld metal apparently caused the transverse cracks

to occur. Both plates ET-9 and ET-10 showed a reduction in thickness near the center of the plate of between 8% and 10%.

Figure 19 shows test plates ET-11 and ET-12 after testing. Both were made with the axis of the weld perpendicular to the principal rolling direction. ET-11 was made similar to ET-10, using electrodes as received, no preheat, and an interpass temperature of 75° F. ET-12 was made similar to ET-9 using rebaked electrodes and a preheat and interpass temperature of 250° F. Neither plate showed any signs of failure after the first explosion at −50° F. Plate ET-11, which contained the microfissures, failed primarily along the heat-affected zone after the second explosion. A few small cracks came to the surface in the weld metal. Plate ET-12, which contained the sound weld, separated into two pieces after the second explosion. Two transverse cracks also developed across the weld metal and ran into the plate for several inches. Since both plates failed primarily along the heat-affected zone, it appears that the directional properties of firebox quality plate, due to rolling, has very little, if any, influence on the path that the failures will follow.

All of the foregoing explosion tests indicate that the welds made with the E11016 electrode and a carefully controlled procedure are very tough. Another indication of the impact properties of the weld metal is shown in Fig. 20. These are transition curves plotted from the results of both Charpy "V" and Keyhole-notch-impact specimens. You will note that again the rebaking of the electrodes and the addition of preheat augmented the toughness properties of the weld metal. The reader's attention is also specifically directed to the fact that these transition curves apply only to weld metal deposited in the horizontal position. The use of larger weld beads and other positions, such as vertical and downflat, can change these curves considerably.

Since many of the Navy explosion-test plates failed in or near the heat-affected zone, an effort was made to see if the standard "V"-notch Charpy specimens would give any indications of loss of notch toughness in that area. Figure 21 shows a transition curve for the metal in the heat-affected zone with the transition curve No. 1 from Fig. 20 added for comparison purposes. Both curves have a peculiar shape which may be due entirely to the welding procedure used. Please note that both curves are from weldments that were made in the horizontal position, using high restraint, rebaked electrodes and a preheat and interpass temperature of 250° F. Your attention is again called to the fact that the Charpy "V"-notch specimens do not indicate any measurable loss of toughness in the heat-affected zone.

Why then did so many explosion tests fail along the heat-affected zone? Either there is an impairment of the notch toughness in the heat-affected zone due to welding that cannot be detected by the standard Charpy tests, or else the geometrical and metallurgical notch effect of the weld and heat-affected zone is causing the failure. It is felt that if the weld reinforcement had been entirely removed and all undercut areas faired in smoothly with the plate, there would have been fewer failures in the heat-affected zone. However, these tests were performed to see how a weld typical of field construction would perform under plastic loading. In all of the plates a great amount of plastic yielding, as shown by reduction in plate thickness (8% to 22%), occurred prior to any failure. This is excellent performance.

## Conclusions

1. Several large field erected spherical pressure vessels of T-1 material have been built and placed in service using a working stress of 32,400 psi. The vessels were not stress relieved. Some welding troubles were encountered but were quickly overcome through the use of preheat and re-drying of the electrodes.

2. Standard tests as suggested by

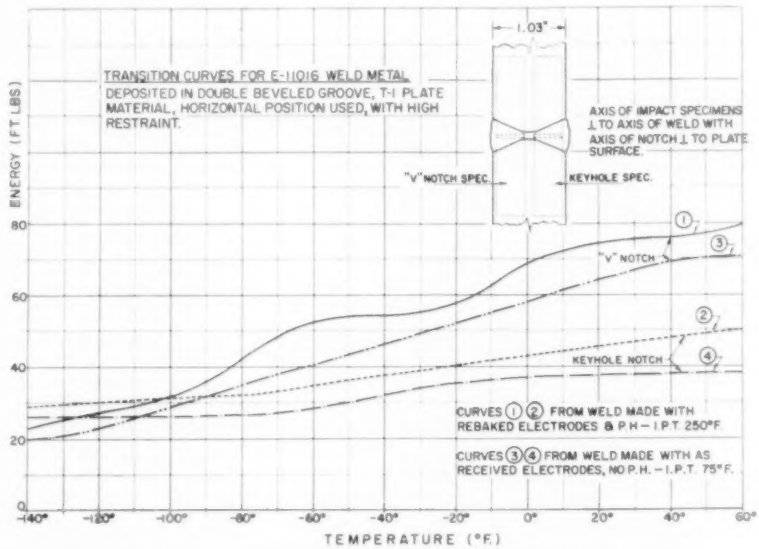
1.03"
TRANSITION CURVES FOR E-11016 WELD METAL
DEPOSITED IN DOUBLE BEVELED GROOVE, T-1 PLATE MATERIAL, HORIZONTAL POSITION USED, WITH HIGH RESTRAINT.
AXIS OF IMPACT SPECIMENS ⊥ TO AXIS OF WELD WITH AXIS OF NOTCH ⊥ TO PLATE SURFACE.
"V" NOTCH SPEC.
KEYHOLE SPEC.
ENERGY (FT. LBS.)
"V" NOTCH
KEYHOLE NOTCH
CURVES ① ② FROM WELD MADE WITH REBAKED ELECTRODES & P.H. – I.P.T. 250°F.
CURVES ③ ④ FROM WELD MADE WITH AS RECEIVED ELECTRODES, NO P.H. – I.P.T. 75°F.
TEMPERATURE (°F.)

Fig. 20 Keyhole and "V"-notch transition curves for E11016 weld metal

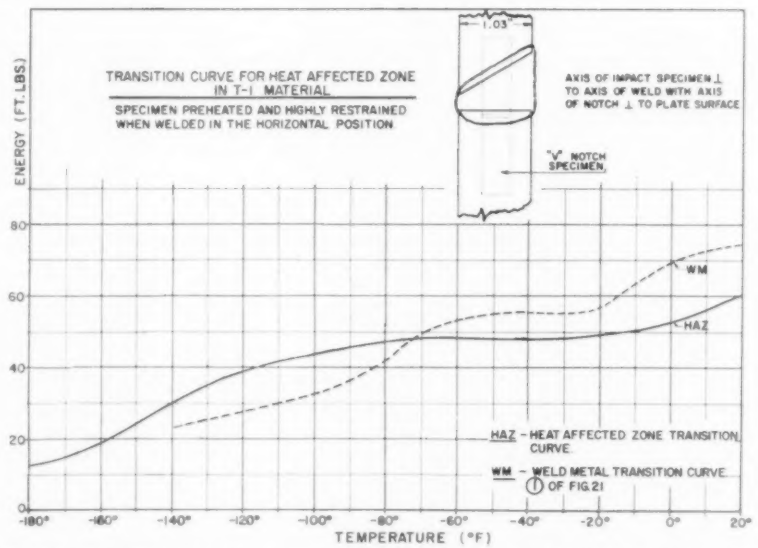
1.03"
TRANSITION CURVE FOR HEAT AFFECTED ZONE IN T-1 MATERIAL
SPECIMEN PREHEATED AND HIGHLY RESTRAINED WHEN WELDED IN THE HORIZONTAL POSITION
AXIS OF IMPACT SPECIMEN ⊥ TO AXIS OF WELD WITH AXIS OF NOTCH ⊥ TO PLATE SURFACE
"V" NOTCH SPECIMEN
ENERGY (FT. LBS.)
WM
HAZ
HAZ – HEAT AFFECTED ZONE TRANSITION CURVE.
WM – WELD METAL TRANSITION CURVE ① OF FIG. 21
TEMPERATURE (°F.)

Fig. 21 Transition curve for heat-affected zone with curve No. 1 of Fig. 20 added for comparison

various codes may not satisfactorily prove the welding procedure when high-tensile material is used. A restraint factor should be added.

3. Welding electrodes must be carefully tested under various conditions before they are selected for use on high-tensile material. The conditions of restraint, interpass temperature and moisture content of the electrode coating must be evaluated.

4. A moisture content of 0.20% in the coating of high-tensile-strength electrode is not low enough for satisfactory use on highly restrained weldments of T-1 material without preheat.

5. Small microcracks in the weld metal that cannot be detected by radiographic inspection do not seriously affect the weldment performance, as shown by the explosion tests. These microcracks can be eliminated by using electrodes with a low moisture content together with a 150° F minimum preheat.

6. A moderate preheat of 250° F on 1-in. thickness material quite satisfactorily eliminates weld-metal cracking without lowering the notch toughness of the heat-affected zone. Additional data should be obtained before assuming that satisfactory results similar to those above might be expected on much lighter material.

7. At the present time it appears that the weld metal from the E11016 electrode (without vanadium) has the best physical characteristics. It has good notch toughness, strength comparable to the T-1 material, excellent ductility, and will take the stress-relieving treatment without becoming embrittled.

8. Storing of these electrodes in an oven for 24 hr at a temperature of 500° F, or rebaking for 1 hr at a temperature of 800° F is necessary in order to pull the moisture content in the coating down to 0.10%. The electrode manufacturers are urged to work on a solution of this problem so that the fabricator will not have to do this rebaking in the field.

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# THE ELECTRO-SLAG WELDING PROCESS

The November 1956 issue of the Russian magazine *Welding Production* featured three articles on electro-slag welding. The process has received official attention as a means of increasing the productivity of labor under the sixth 5-year plan.

1. "The Fatigue Strength of Welds in Heavy Sections Made by the Electro-Slag Process," by I. V. Kudryavtsev and N. M. Savvina.


Abstracted by Gerarld E. Claussen.
Dr. Claussen is associated with the Development Laboratories, Linde Company, Newark, N. J.


The joint to be tested had a cross section of $1^3/_{16}$ x 6 in. in plates 6 in. thick. The joint was in the vertical position and was 20 in. high. The composition of plate and weld metal is given in Table 1. The FTS-7 flux contained 45.6% $SiO_2$, 27.6% MnO, 2.39% $CaF_2$, 2.69% $Al_2O_3$, 16.19% MgO and 5.94% CaO. Two $^1/_2$-in. electrodes of steel Sv-15G were used. The depth of fused flux (slag) was $2^3/_8$ in. The electrodes extended 2 in. from guide tube to top of slag. The rate of feed of electrode was 130 ipm and the speed of motion of the oscillating head was 18 ipm. Current and voltage were 500–550 amp and 45–50 v, respectively. The electrodes were 3 in. apart and remained stationary 7 sec at the end of each oscillation. The distance between electrodes was calculated from the formula: $d = L/P + 0.24$ in., where $L$ is length of bath and $P$ is number of electrodes.

Tensile and notch impact values at room temperature are given in Table 2. The weld metal microstructure was Widmanstätten as-welded, and equiaxed after normalizing. The pulsating ten-


(*Continued on page 392-s*)


Table 1—Chemical Composition, %, of Plate and Electro-Slag Weld Metal

| | *C* | *Si* | *Mn* | *P* | *S* | *Cu* |
|---|---|---|---|---|---|---|
| Steel 22K | 0.18 | 0.19 | 0.76 | 0.017 | 0.032 | Trace |
| Weld metal | 0.22 | 0.26 | 0.78 | 0.018 | 0.026 | Trace |

Table 2—Tensile and Notch-Impact Results on Joints Welded by the Electro-Slag Process

| *Heat treatment* | *Specimen* | *Yield strength, 1000 psi* | *Tensile strength, 1000 psi* | *Elongation, %* | *Reduction area, %* | *Notch-impact value, mkg/cm²* | *Brinell hardness* |
|---|---|---|---|---|---|---|---|
| As-welded | Plate | 31–35 | 64–84 | 29–30 | 53–55 | 9.3–11.0 | 143 |
| As-welded | Heat-affected zone | 35–39 | 62–78 | 24–30 | 49–62 | 7.5–11.8 | 143 |
| As-welded | Weld | 36–39 | 66–70 | 23–29 | 49–60 | 6.4–11.6 | 143 |
| 2 hr at 1200° F | Plate | 31–36 | 62–64 | 31–37 | 49–61 | 8.1–14.7 | 143 |
| 2 hr at 1200° F | Weld | 30–34 | 59–61 | 23–28 | 53–60 | 4.4–14.0 | 143 |
| Normalized 1 hr at 1690° F | Plate | 37–40 | 65–68 | 26–35 | 38–64 | 12.4–14.2 | 143 |
| Normalized 1 hr at 1690° F | Heat-affected zone | 39–41 | 65–67 | 23–32 | 61–63 | 12.3–13.2 | 143 |
| Normalized 1 hr at 1690° F | Weld | 37–38 | 60–72 | 33–35 | 60 | 12.3–13.7 | 143 |

# STUDIES OF WELDING ARCS USING VARIOUS ATMOSPHERES AND POWER SUPPLIES

*Authors report results of preliminary survey of a broad program to study many of the variables connected with the consumable-electrode gas-shielded welding of steel*

BY T. B. HAZLETT AND G. M. GORDON

## Introduction

The mechanism of metal transfer across a welding arc has been the subject of sporadic study by scientists and engineers for many years. Approximately thirty years ago, Hilpert[1] reported on high-speed motion-picture studies of the phenomena. Since that time, Doan and co-workers extended the work and included an investigation of the influence of various atmospheres on weld deposits. This early work was reviewed by Spraragen and Lengyel in which all of the pertinent literature up to 1942 was summarized.[2] This survey serves to emphasize the fact that many details of the physics of the arc and of metal transfer were the subject of speculation only at the time and many of them have not yet been clarified.

World War II, which dramatically demonstrated the importance of arc welding to high production, was instrumental in adding practicality to fundamental studies of welding arcs and hastened the use of more refined scientific techniques. Major impetus was given to such studies by the work of Muller and co-workers.[3, 4] They found large differences in arc and metal-transfer characteristics when different shielding gases were used. Their work also disclosed the sudden transition in the mechanism of metal transfer when the current density was increased to very high values. Ludwig[5] concluded from his studies of drop formation and transfer in argon that the "pinch effect" was a major factor in metal transfer across the arc. Lesnewich,[6] working along different lines, attacked this problem from the standpoint of additions of elements or compounds which decreased the work function. He attributed the improved arc characteristics obtained with oxygen additions to argon to the change in work function. The more recent articles dealing with this general subject[7, 8, 9] have been primarily concerned with the problems associated with the use of $CO_2$ as an arc atmosphere.

The present paper reports results of a preliminary survey which was the initial step in a broad program to study more completely many of the variables connected with consumable-electrode gas-shielded welding of steel.

## Equipment and Procedure

The present study was designed to determine if there was an inherent difference in the arc characteristics when welding with a d-c generator or with rectified a-c. The welding generator was modified to supply essentially constant potential within the current range under study. Figure 1 shows the power supply characteristics of (1) the generator as received from the manufacturer, (2) the generator after modification, and (3) the characteristics of the rectifier unit. It may be seen that the latter shows a slightly decreasing voltage-current curve, whereas the curve for the modified motor-generator shows slightly rising voltage-current characteristics in the range of 200–350 amp. This difference was not considered significant for the investigation.

A commercial automatic feed, inert-atmosphere welding gun was mounted at an angle of eighty degrees to the work and the work moved relative to the gun at a speed of 15 in./min. All atmospheres were used at a flow rate of 60 cfh.

Deposits were made on freshly machined surfaces of $^3/_4$-in. thick AISI, 1020 rolled plate using $^1/_{16}$-in. diam mild-steel welding wire having a nominal composition of 1% Mn and 0.15% carbon. All deposits were made with

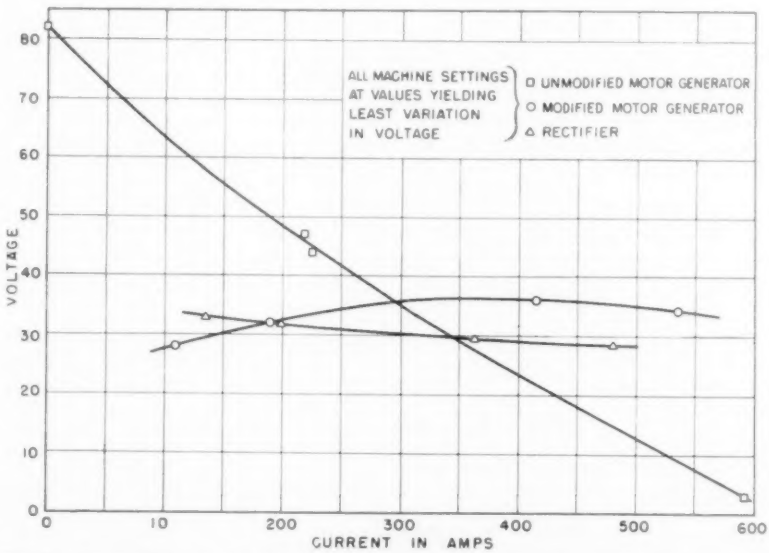


Fig. 1 Characteristics of motor-generator and rectifier welding machines

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Presented at the 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

Table 1—Test Conditions

| *Atmosphere* | *Code* | *Power supply* | *Polarity* | *Arc voltage* | *Welding current* | *Rod feed (in./min.)* |
|---|---|---|---|---|---|---|
| $CO_2$ | (a) | M. G. | Straight | 27.5 | 260 | 243 |
| | (b) | Rect. | Straight | 28 | 260 | 215 |
| | (c) | M. G. | Reverse | 27 | 265 | 190 |
| | (d) | Rect. | Reverse | 28 | 250 | 170 |
| Helium | (a) | M. G. | Straight | 27 | 240 | 243 |
| | (b) | Rect. | Straight | 28 | 250 | 257 |
| | (c) | M. G. | Reverse | 27 | 240 | 183 |
| | (d) | Rect. | Reverse | 28 | 240 | 183 |
| Argon | (c) | M. G. | Reverse | 27.5 | 265 | 165 |
| | (d) | Rect. | Reverse | 28 | 260 | 174 |
| Argon + 5% $O_2$ | (a) | M. G. | Straight | 27.5 | 260 | 197 |
| | (b) | Rect. | Straight | 28 | 250 | 197 |
| | (c) | M. G. | Reverse | 27.5 | 255 | 150 |
| | (d) | Rect. | Reverse | 28 | 255 | 144 |

arc voltages of 27–28 volts and currents between 240 and 265 amp.

Surface beads were made in atmospheres of $CO_2$, helium, argon and argon + 5% $O_2$ using both power supplies. Straight and reverse polarities were investigated for all conditions except straight argon where reverse polarity only was employed. The test conditions are given in detail in Table 1. All of the subsequent figures in this paper utilize the code in the table, e.g., (a) indicates a bead made with straight polarity with the motor-generator power supply.

High-speed motion pictures of the arcs were taken at a maximum speed of 5000 frames/second while the current and voltage traces were recorded simultaneously using a direct-writing recorder of the hot wire stylus type. The response of this recorder was better than 60 cycles/second but unfortunately the traces were not too legible at very high pen speeds. Consequently, these records were not directly reproducible but have been traced for presentation in Figs. 2 and 3.

Surface appearance, penetration and bead shape were noted and are shown in Figs. 4, 5 and 6.

## Experimental Results

Some of the most graphic results of this investigation were revealed only by the colored high-speed motion pictures; in most cases the density of the photographic negatives was too great for successful black and white reproductions. Consequently, a verbal description will have to suffice to describe the mechanism of the metal transfer under the various conditions.*

### *Results with $CO_2$*

The mechanism of metal transfer in a $CO_2$ atmosphere is of considerable interest. The molten end of the welding wire was found to form a very large drop that was supported by the gas pressure in the arc column that formed between the bottom of the drop and the plate. This arc was extremely short and it appeared that the heat was transferred to the rod by convection of the molten drop. The drops were heated at the bottom by the arc and this heat was transmitted by a rolling action of the molten metal to the rod, causing additional melting. Eventually, the weight of the drop became so great that the upward force of the arc could no longer support the drop. It then touched the plate with the short circuit producing an explosive action; this action is apparently the cause of the high degree of spatter connected with all $CO_2$ welding.

The mechanism of metal transfer is apparently the same for both straight and reverse polarity but the size of the molten drops was far less for reverse polarity. The molten drops appeared to be quite cold and an oxide film was clearly discernible on the surface. Rothschild[3] stated that he was unable to convert this arc action to a spray even with 1000 amp in $^1/_{16}$-in. diam wire.

Current and voltage fluctuations are shown in Fig. 2 in which the two deposits made with straight polarity are shown at the left while the traces at the right were made with the wire positive. There is no significant difference in results obtained from the two power supplies insofar as fluctuations of voltage or current during welding are concerned. Similarly, the high-speed pictures showed practically identical arc characteristics produced by the two welders.

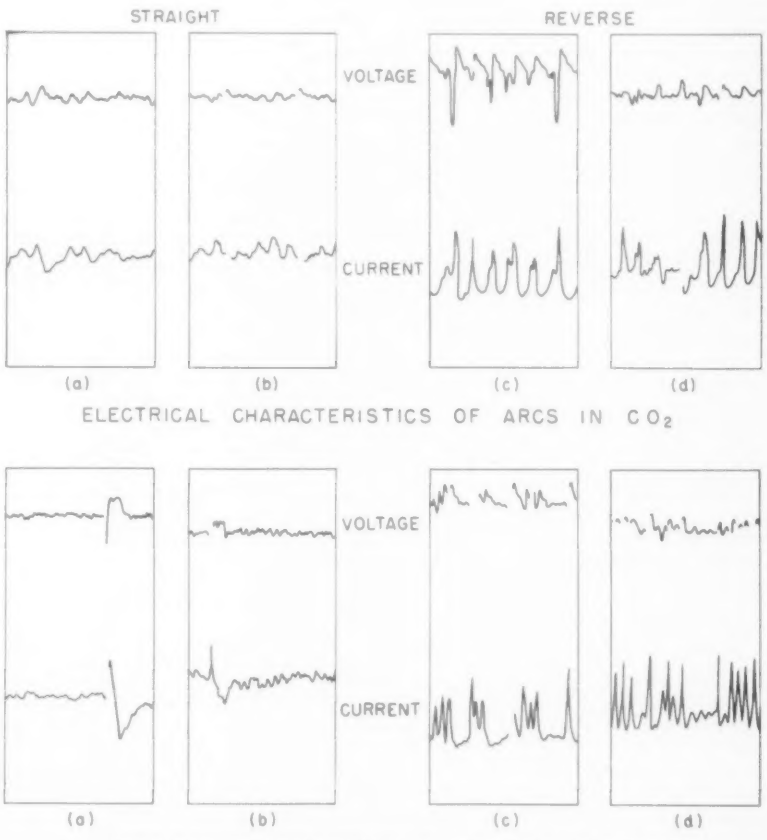


Fig. 2 Electrical characteristics of arcs in $CO_2$ and in helium

* A colored moving picture was shown when the paper was presented verbally. This film is available for loan from authors.

The surface appearance of these beads is shown at the top of Fig. 4, while the depth of penetration and bead shape are illustrated in Fig. 6. It may be noted from the latter that the deposits made with straight polarity are relatively flat with moderate to shallow penetration. On the other hand, the deposits made with reverse polarity reveal deep penetration and a much higher bead. Bead (b) in Fig. 4 shows a much less regular contour than (a). There is no apparent reason for the different appearance of these two beads either in the arc action revealed by the motion pictures or in the current-voltage traces. On the other hand, beads (c) and (d) are quite comparable.

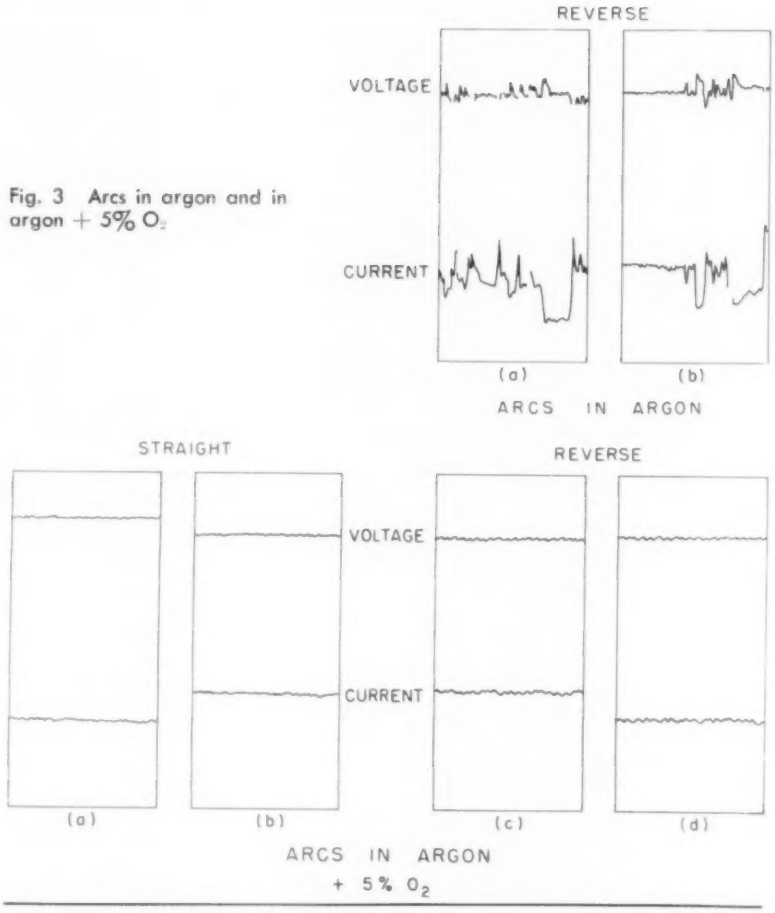


Fig. 3 Arcs in argon and in argon + 5% $O_2$

### Results with Helium

Current-voltage traces made during deposition of beads under a helium atmosphere are also given in Fig. 2. Again, there is no significant difference in the appearance of the traces produced by the different power supplies. The motion pictures show that the droplet action in the helium atmosphere is similar to that in $CO_2$. However, a significant difference is that the helium was intermittently excited. This periodic glow discharge showed as a blue glow within the arc plasma in the picture. When this occurred the plasma extended up the welding wire a significant distance and the wire was heated from the sides. The remainder of the time the arc was confined to the region between the bottom of the drop and the work. The mechanism of metal transfer was essentially the same as for deposits in $CO_2$; the droplet size was considerably smaller for reverse polarity than for straight and the metal transfer was more continuous in nature. Beads produced in this series are also shown in Figs. 4 and 6.

The deposits in general were quite smooth in appearance but the edge of the bead was less regular when the motor-generator set was used than when the rectifier was employed on straight polarity. The bead quality as revealed by the cross sections was not as satisfactory as for $CO_2$; a high degree of porosity was present near the top of the deposits. Beads made with straight polarity were not as flat for helium as for $CO_2$.

### Results with Argon

Current and voltage characteristics of welds made under an atmosphere of pure argon with reverse polarity are shown in Fig. 3. In this case, significant differences in the arc action were found for the two different types of power supply. The motor-generator traces were consistently more erratic than those from the rectifier. This difference was reflected in the motion picture. The metal transfer in the case of the motor generator was by a combination of freely falling drops and the successive shorting as found in the $CO_2$ and helium welds. On the other hand, the arc produced by the rectifier had a relatively smooth appearance and, in many cases, the flow of molten metal could be compared to the dripping action of cold molasses. The pictures are, of course, in this respect somewhat deceptive since it would be impossible to have a continuous molten metal stream. The metal probably transferred as discrete droplets surrounded by a high intensity iron vapor plasma.

This is the only case studied in which any significant difference was found with the two different types of power supply. The appearance of the beads and their cross sections is given in Figs. 5 and 6. It may be seen that bead (d) was considerably broader and flatter than (c). This difference correlated with the oscillographic traces and the motion picture. There was an appreciable amount of fine spatter immediately adjacent to both beads, but particularly (c).

### Results with Argon + 5% $O_2$

The extreme smooth arc action produced when 5% oxygen is present in argon is shown by the current voltage traces in Fig. 3. This uniformity of arc action was also revealed in the motion picture in which the metal was transferred by discrete droplets within a plasma having two distinct regions. It is believed that the inner cone was iron vapor and the surrounding envelope a mixture of excited argon, oxygen and iron vapor. The droplet formation sequence for both straight and reverse polarities are shown in Fig. 7. At the particular current and voltage used in this study, these drops were transferred at a rate of 30–40 per sec. The difference in arc length with straight and reverse polarities (when the same voltage was used) is clearly evident in Fig. 7. The difference in rate of metal transfer is shown by the rod feed values given in Table 1.

## Summary

For $CO_2$, helium and argon plus 5% oxygen, no significant difference in arc characteristics, bead shape, or penetration was found between using a modified motor-generator set or rectified a - c. For pure argon, however, significant differences in arc action and bead shape were observed.

From high-speed motion picture

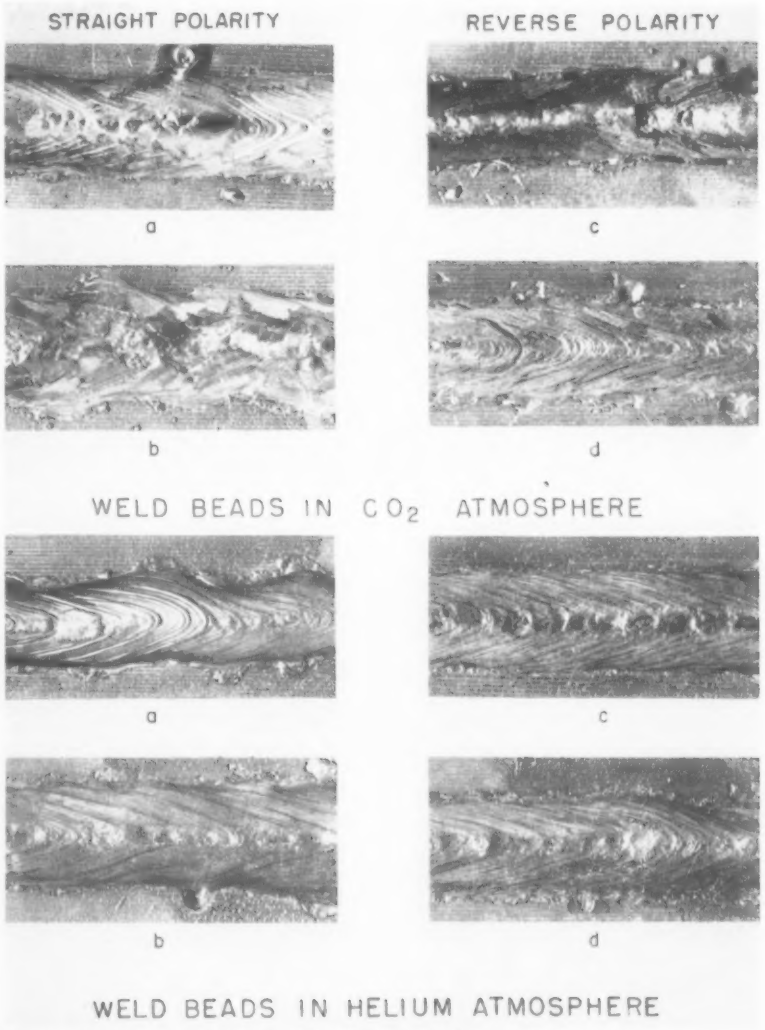


Fig. 4 Weld beads in $CO_2$ and in helium atmospheres

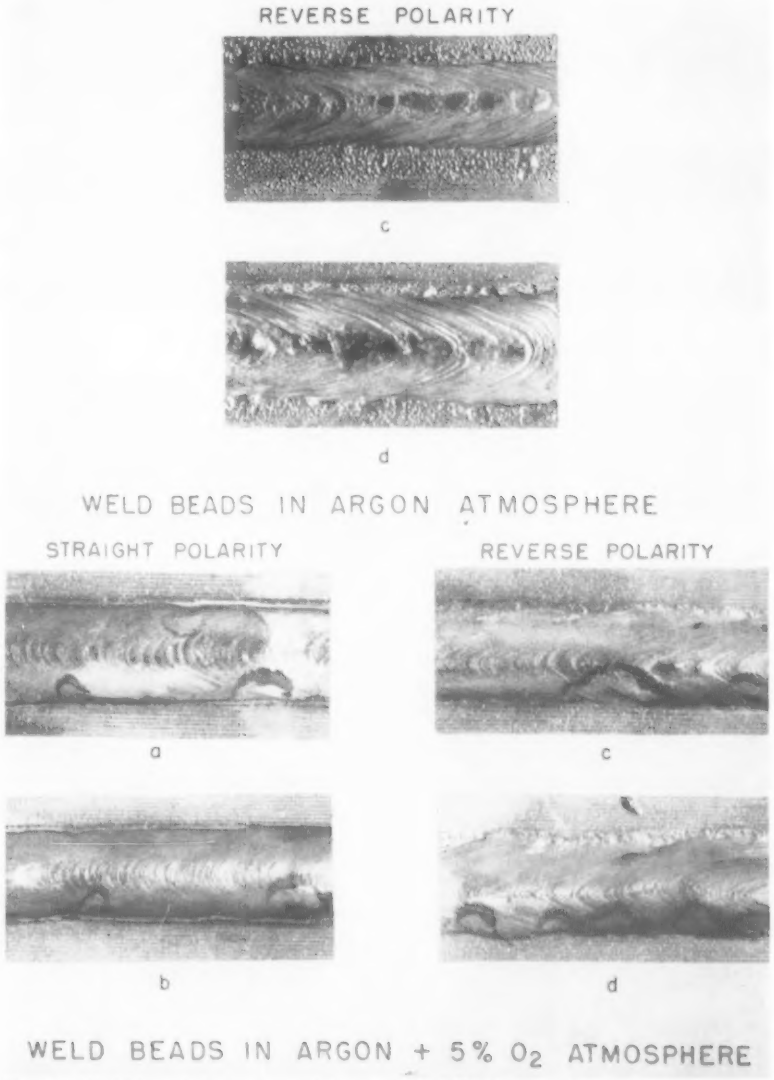


Fig. 5 Weld beads in argon and in argon + 5% $O_2$ atmospheres

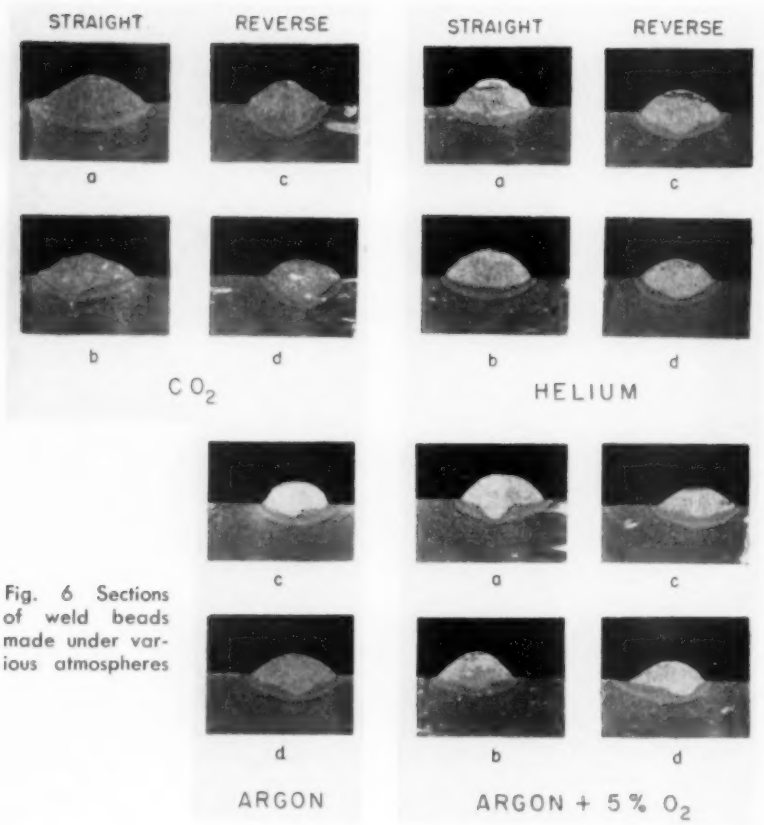


Fig. 6 Sections of weld beads made under various atmospheres

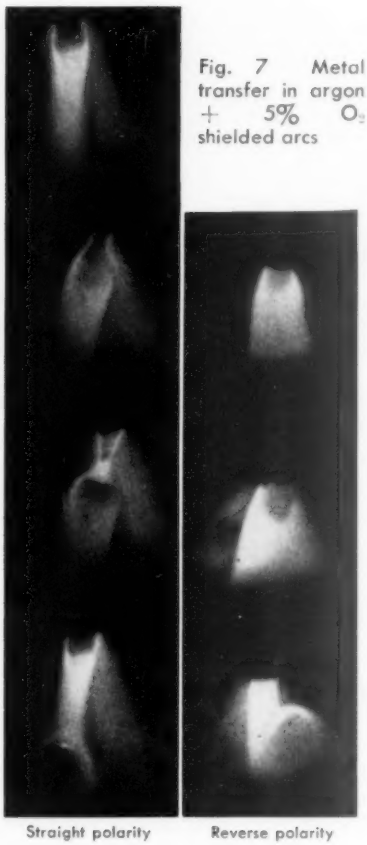


Fig. 7 Metal transfer in argon + 5% $O_2$ shielded arcs

studies, it was observed that metal, current and heat are transferred by several mechanisms. One of these, which occurs when $CO_2$ is used as the shielding gas, is the formation of large molten drops that are attached to the welding wire and supported by the pressure of the arc column. When the weight of the drop exceeds the arc force, the drop touches the work, causing a short circuit that almost explosively detaches the drop. The other mechanism present with argon plus oxygen shielding, is by small discrete metal droplets being transferred smoothly across the arc from the wire to the work. Metal transfer in atmospheres of helium and pure argon may be described as a mixture of these two with ionization and excitation of the gas to metastable states being important factors.

*Acknowledgment*

The authors wish to thank the Office of Ordnance Research, U. S. Army, whose support has made this research program possible. They also wish to thank E. R. Parker for his interest and helpful discussions during the course of this work. The experimental assistance of R. Regan and R. Baender is also acknowledged.

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# DESIGN—ITS INFLUENCE ON RESIDUAL STRESS AND BRITTLE FRACTURE

*Paper discusses the relationship of residual stresses to brittle fracture as experienced in railroad car components; also, it points out the important influence of design in alleviating the difficulty*

BY J. L. THOMAS

## Introduction

This paper discusses the work done by the Research and Development Department in studying the subject of brittle fracture in one of the components of car construction. It endeavors to show the relation of residual stress to such fracture and the important influence of design in alleviating the difficulty.

Any attempt to explain the phenomena of brittle fracture would be highly presumptuous considering the great amount of effort and time that has been spent on this subject over a period of many years by eminent authorities in the field.

It would seem the question of brittle fracture was first raised, as a matter of record, in a meeting of the British Iron and Steel Institute in 1879 by Nathaniel Barnaby. It is further recorded that Barnaby did not receive a satisfactory answer to his question, and the meeting broke up in disorder.

At present there still seems to be some lack of general agreement as to causes and origin of brittle fracture. Now, since any mention of brittle fracture immediately involves the second subject of residual stress, we must define what we mean by the term "residual stress." The most simple and all-inclusive definition would seem to be, "stresses existing in bodies completely divorced from any external forces."

The different kinds of residual stresses in steel and the origins of each are many and varied; but for the purpose of this presentation, we are concerned with residual stresses from any and all causes, since we are interested in all residual stress in its effect on the design.

Let us say that we admit residual stresses can be caused from variations in temperatures and pressures in the rolling operation and from metallurgical differences before and after rolling. Most certainly, welding can create residual stress. Many authorities classify welding stresses as "local residual stresses," and there is also a separate definition, "reaction residual stresses."

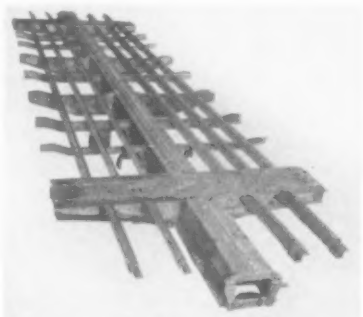


Fig. 1 PS-1 conventional 21-in. welded bolster with underframe assembly

These different forms of definition of residual stresses are for the purpose of determining stored energy, and while they are important in a residual stress analysis, they are not given separate definition here.

It might be asked at this point, what is the difference in action of stresses defined under our broad definition as residual and those described as working stresses? At what point and under what circumstances are they superposed? Under what conditions are all of these stresses neutralized, working adversely, or working to the advantage of the weldment, particularly under conditions of high temperature differential?

It would be well to quote from William Spraragen in William Osgood's compilation on residual stresses: "The point which is important is that residual stresses usually promote plastic flow, in exceptional cases they may be used to retard it. The beneficial or adverse effects of residual stresses, therefore, depend on whether this expediting or retarding of plastic flow is helpful or harmful."

Also, Harris in Osgood's compilation states that: "The 'proof' of the adverse influence of high residual stress rests, therefore, on the continued experience that its 'control' leads to satisfactory fabrication."

It is the argument of this paper that each specific case requires a great deal of investigation and continued testing to establish the effect of residual stresses in a welding composite. We are unable to accept the complete accuracy of a seemingly well established opinion that residual stresses induced in a welded composite structure become "self relieving" when such composites or components are subject to working strains. It might be argued that, depending on the configuration of the design, such residual stresses might not be "self relieving" but, on the contrary, could

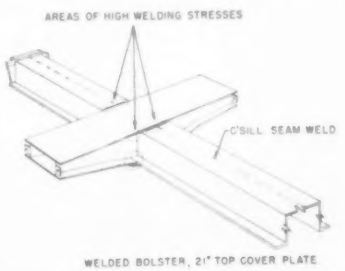



Fig. 2 Areas of high welding stresses

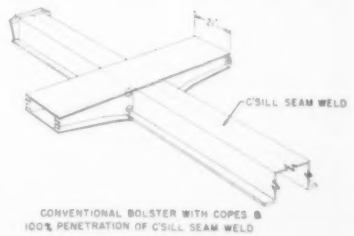



Fig. 3 Typical web "copes" and center-sill seam weld

**J. L. Thomas** is Consultant, Process, Methods and Fabrication, Pullman-Standard Car Mfg. Co., Hammond, Ind.

Presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

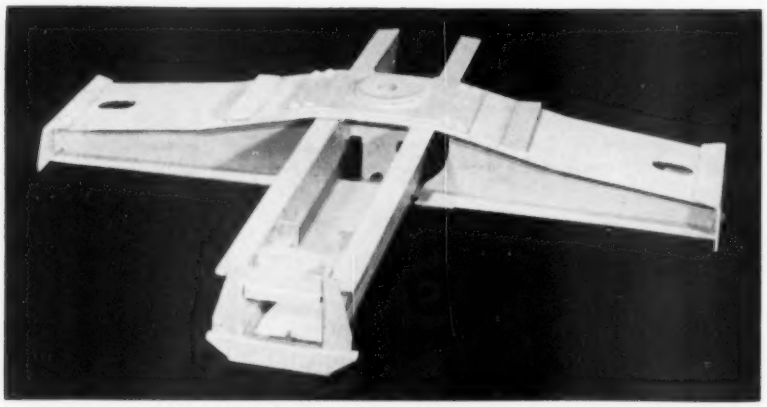


Fig. 4 Open web bolster—bottom view with open webs and one-piece bottom cover plate

account for failure from premature fracture.

It would seem logical that procedure and various techniques developed for laboratory usage in setting up tests for residual stress and in working with laboratory specimens, usually encounter difficulty in establishing firm evaluation and only indicate some order of magnitude.

Again, to quote Campus from Osgood's compilation: "The measurement of residual stresses requires more caution than the measurement of ordinary stresses, and the measurement of residual stresses often has more the qualitative significance of a proof of the existence of residual stresses rather than the quantitative significance of a precise determination." The many tests conducted in this field by recognized authorities would seem to bear out the truth of the Campus quotation.

In general, laboratory specimens do not reproduce the effects of residual stresses in large structures, which in essence, represent an assembly of many components. But if the laboratory test establishes any appreciable order of magnitude, such information should be of great value as an aid in the design of the final structure.

However, we leave the analysis of residual stresses with its many ramifications in the hands of those far better qualified and state simply that we feel that residual stresses do contribute to brittle fracture. Now a brief case history of a specific fracture problem in actual railway car components will be presented with the results attained in alleviating this problem. By designing the component with the primary objective of reducing the residual stresses to a comparatively lower level, we have attained a much more satisfactory solution to our fracture problem.

### Brief History of Box Car Bolster Fracture Problem

The fracture problem is a matter of serious concern to the manufacturers of freight cars and to the operators. A survey was made several years ago in which some 5000 box cars of various builders were examined and a small percentage of these cars were found to have fractures in the bolster center sill region.

All bolsters must meet the specifications of the American Association of Railroads with the result that such bolsters have generally exhibited satisfactory service performance. Our original welded bolster, with none of the later improvements directed toward increased low-temperature fracture resistance, was substantially stronger than the standard AAR type as determined by both static and dynamic tests of full size specimens. When this bolster was impact tested in a fully loaded car at ambient temperatures, it withstood repeated impacts at 10 mph without fracture. Only when tests were conducted with the bolsters refrigerated, were brittle fractures experienced. Generally the field inspections of cars in service showed its performance to be highly satisfactory until

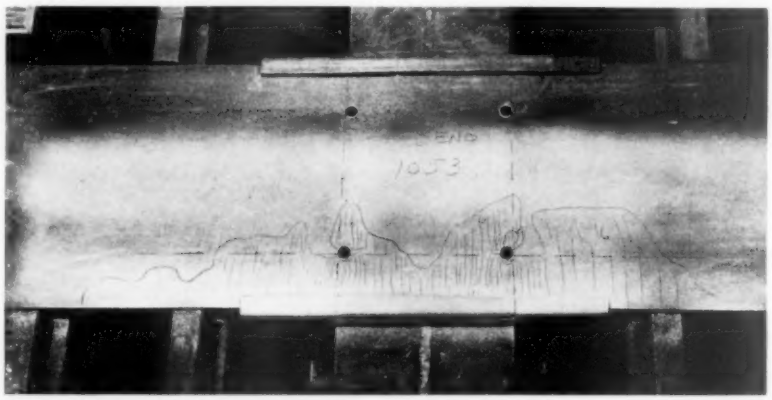



Fig. 5 Open web bolster—top view with "stress relief" holes and restraining clamp arrangement

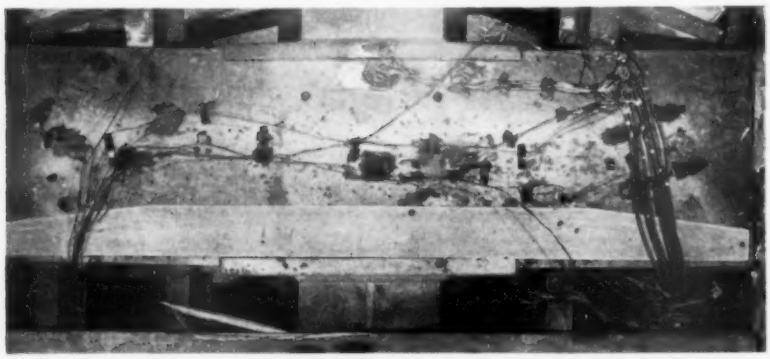


Fig. 6 Straight-edge measurement at top cover plate inboard edge—"horizontal deformation" after 12 mph impact, $^1/_4$ in.

higher speed train make-up developed. Then all types of bolsters began to show occasional brittle fractures depending on how frequently the combination of high impact speed, rigidly-loaded cars and extremely-low temperature was encountered.

Time does not permit a complete history of the many tests conducted over a period of years, but certain salient points developed in our search for better performance will be presented.

Our research tests were conducted on an impact testing ramp built for dynamic testing of railway cars. The ramp is designed to produce impact speeds up to 18 mph.

In testing the car bolster-center-sill area, the test car was usually loaded with steel billets secured with cribbing to insure a highly compact load in order to concentrate impact forces in the car underframe. The striking or hammer car was a 50-ton hopper car loaded with kiln-dried sand to its rail capacity of 169,000 lb.

At the higher impact speeds, forces in excess of 1,000,000 lb were recorded between the struck and the striking car. To give some idea of ratio of impact speed and force developed, one mph equals 100,000 lb of force, thus 12 mph would equal approximately 1,200,000 lb.

This test procedure is purposely far more severe than would be expected in the most extreme service conditions. The test car load of steel billets is secured with cribbing and compacted to secure maximum rigidity. Our purpose in impact tests of this nature is to create fracture at lowest possible impact speed.

The test car was instrumented with strain gauges, accelerometers and other forms of instrumentation to measure its forces and action. The signals from these instruments were carried to the instrument room where they were recorded on photographic paper for later study and analysis. High speed cameras were also used as further aid in analysis.

In over 250 impact tests many types of bolster and bolster-center-sill configurations and arrangements have been tested including conventional bolster types, riveted or welded. From information gained in these various tests, the following general facts have been established:

1. The substitution of a 26-in. wide rectangular cover plate for the conventional 21 in. width, with no other changes, did not prove satisfactory. However, the 21-in. top cover plate with the latest copes and production welding sequence showed considerable improvement.
2. The use of a material less notch-brittle at critical temperatures does minimize fracture. However, such material as a replacement of open-hearth steel adds an economic burden where cost is a very important factor.
3. More satisfactory experimental results, as developed in our research experience, have been obtained by meticulous attention to designing to avoid notches and stress concentrations or, wherever practical, to locate these stress concentrations in areas of lower working stress levels, and by incor-

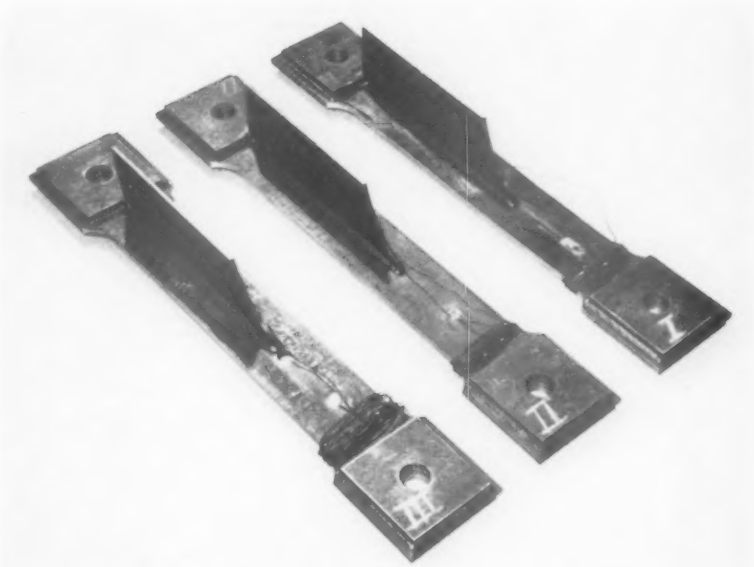


Fig. 7 Front view of three tensile specimens, all dimensions identical, thermocouple leads attached

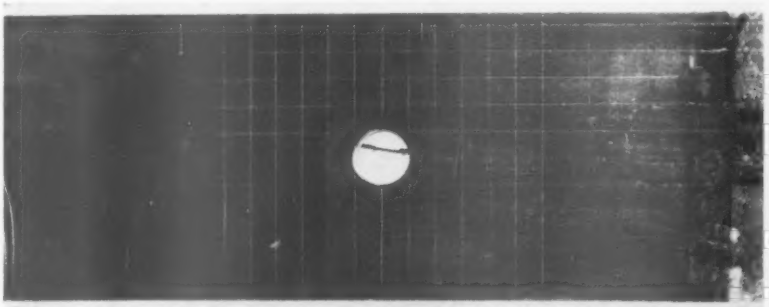


Fig. 8 Back view of specimen III; grid lines typical

Fig. 9 Specimen in testing machine ready for pull test. Note refrigeration tank at lower left

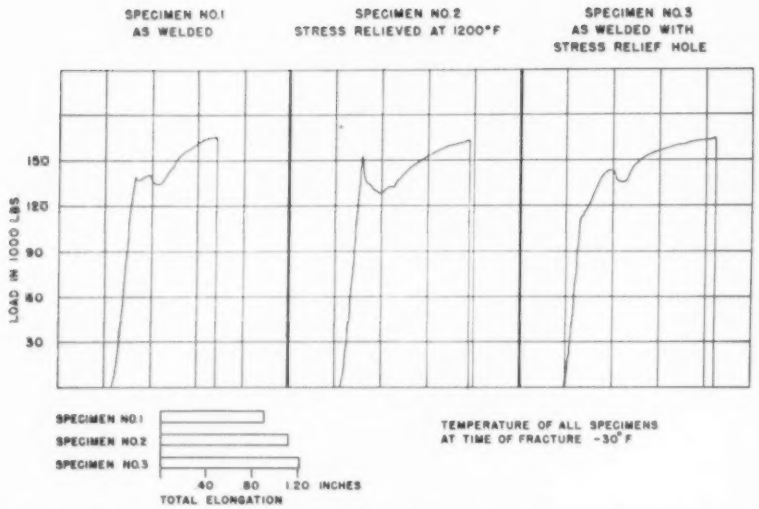



Fig. 10 Reproduction of recorder chart from the testing machine. Insert at bottom is added to show comparative elongation

Fig. 11 The three specimens after fracture

porating stress-relief "copes" and holes in areas of high stress concentrations.

Our most encouraging results have been accomplished with this concept as the objective; and it covers, in general, the areas which we wish to emphasize in this presentation.

Figure 1 shows typical conventional welded bolster with 21 in.-wide top and bottom cover plates, assembled in box car underframe.

The conventional 21-in. welded bolster, indicating areas of welding stress concentrations, is shown in Fig. 2.

Figure 3 shows the development of the cope at center sill and bolster web junction. The center sill joining weld was increased to 100% penetration in the bolster areas.

Open-web experimental bolster is shown in Fig. 4. Butt welds are removed at junction of center sill and bolster webs. Lower cover plate is one piece and "sole plate" is combined with bolster center plate.

***Open-Web Bolster (Experimental)***

In the open-web bolster, as developed in the Research Laboratory, we eliminated the butt welds at the junction of lower cover plates to center sill flanges. This was accomplished by using a one-piece lower cover plate. The former separate "sole plate" with its attendant welding was removed by combining the "sole plate" with the bolster center plate. In addition, the former butt-welded connections of bolster webs at vertical face of center sill were completely removed. We thus attempted to eliminate or reduce those areas of high residual stress concentration where in previous tests brittle fracture originated at low temperature levels.

Figure 5 shows the restraining clamps used to prevent local plate buckling since the former transverse welds joining the top cover plate to center sill in previous tests of conventional bolster, proved to be a principal origin of fracture. These transverse welds were omitted in open-web design. The two longitudinal welds not shown in this picture joining the cover plate with center sill are fillet welds, and they terminate approximately one inch from inner edge of the one inch diameter relief holes drilled in top cover plate. The same relief holes and longitudinal fillet welds with the same weld termination is present in previous pictures of bottom view of bolster but is covered by "sole plate"-center plate combination.

Attention should be called to the stress coat pattern in the picture. The car was impacted at 6 mph at room temperature or approximately 70° F.

Both top and bottom cover plates are 21 in. wide and $^1/_2$ in. thick. The material is mild steel to our specification Number 517, commonly called hot-rolled open hearth. However, plate edges are universal rolled mill edge and are not sheared in width. This insures a degree of freedom from notch sensitivity as established by test.

With regard to horizontal deformation (Fig. 6), we are unable to show a

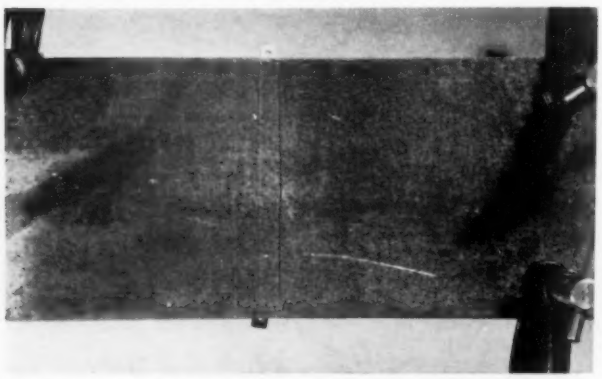


Fig. 12 Method of clamping to close fracture after test

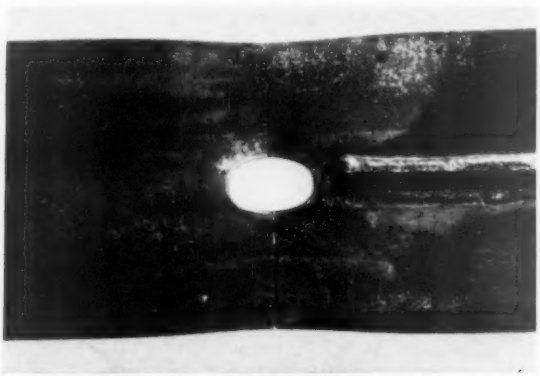


Fig. 13 Specimen III with fracture closed after test. Note original 1-in. hole is now 1.505 x 0.938 in.

direct comparison of the open web with the conventional bolster since deformation tests of the conventional type were made at ambient temperature and the resulting horizontal deformation shows approximately $^9/_{16}$ permanent deformation at 10 mph. In the case of the open-web bolster, horizontal deformation is approximately $^1/_4$ in. at 12 mph, refrigerated to minus 19° F.

Table 1 treats with four welded bolster types and comparative resistance to fracture under impact test in test laboratory. The substitution of 26-in. wide cover plate from the conventional 21 in. width does not show improvement.

In Fig. 7 there are shown the three tensile specimens with thermocouple leads attached. Number I is in "as-welded" condition. Number II has been stress relieved at 1200° F. Number III is in as-welded condition and shows one inch diameter reamed hole in area of expected fracture. All specimen edges are machined to minor width of 5.500 in., to tolerance of 0.005. The major plate width at ends is 8.000 in.; the material is $^1/_2$-in. mild steel, all specimens cut from same plate.

Grid lines, $^1/_2$ in. interval, on back face of specimens are shown in Fig. 8. These grid lines are for elongation measurement after testing.

Figure 9 shows specimen in testing machine ready for test. Two thermocouples were used in every case, one on the web and one on plate of specimen. The temperature at start of the three tests was −30° ±4° F.

In Fig. 10, there is shown an exact reproduction of recorder chart from the testing machine. The load at fracture point in the three tests shows as almost constant (164,000 pounds) and the chart insert at bottom of figure shows elongation.

**Table 1—Impact Performance Comparison of Conventional Welded 21-In. Cover Plate [No Copes in Webs] with Welded Open Web Bolster**

| *Bolster type* | *Test procedure* | *Results* | *Horizontal deformation* |
|---|---|---|---|
| Conventional bolster at −16.7° F | Impacts at 4, 5, 6, mph | Brittle fracture in cover plate–center sill area–struck end at 6 mph | Fracture occurred before any appreciable deformation |
| Open-web bolster average temp. for impacts, 4 to 11 mph −17.8° F 12 mph impact at −19° F | Impacts at 4, 5, 6, 7, 8, 9, 10, 11, and 12 mph | No fracture in bolster at struck end of car. Fracture in top cover plate at opposite end of car at 12 mph | Approx. $^1/_4$ in. at inboard edge of top cover plate at 12 mph |

* Cost of production of open-web and conventional bolster—comparable.

All three specimens after fracture are shown in Fig. 11. The fracture lines are straight and fracture occurred where expected.

Figure 12 is a close-up picture of specimen clamped to close fracture, so that exact elongation measurement can be taken from grid field. The grid lines are faint as we did not affect plate surface or create any form of notch.

Figure 13 is a close-up picture of Specimen III clamped to close fracture. The elongation of specimen and width reduction in area of hole is pronounced. The original hole diameter of 1.000 in. before test is 1.505 x 0.938 in. after test.

Figure 14 shows Specimen I in as-welded condition. This figure shows upper and lower reference lines typical of all three specimens. Final elongation measurements were taken with height gauge and indicator from surface plate. Bar graph comparisons for elongation are true scale. It may be noted that edges of plate, show more elongation than center, due to resistance of the web.

Specimen II is identical to Specimen I, except that it is postheat treated at 1200° F (Fig. 15). Note that elongation at edges and center of specimen are identical at all stations. There is no resistance from web.

Figure 16 shows Specimen III in as-welded condition, except for the one inch diameter reamed hole in plate at web weld termination. Note that elongation of plate above fracture line is greater at edges than at plate longitudinal center line in the same manner as Specimen I. However, elongation is greater at every station than Specimens I and II. The maximum elongation of the three specimens over a 27 in. length shows Specimen I as 0.750 in., Specimen II as 0.938 in. and Specimen III as 1.187 in.

Figure 17 illustrates what can happen as the result of an unintentional weld, or more correctly, a weld not called for in design. In the test of the three specimens we actually made four, one being for purpose of instrument calibration, temperature consistency, etc. In the fabrication of all four specimens, the $^5/_{16}$-in. web was positioned by a tack weld at end of specimen as shown in picture. This tack weld represents a classical example of a "weld notch trigger." We decided to pull test this

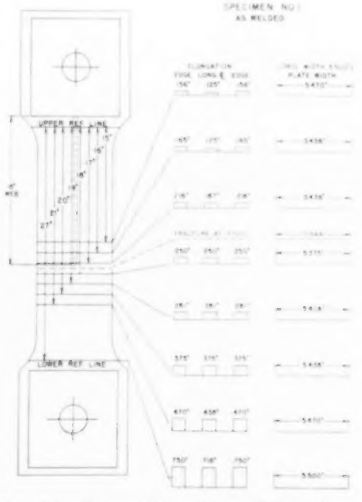



Fig. 14 Elongation chart of Specimen I, as-welded condition

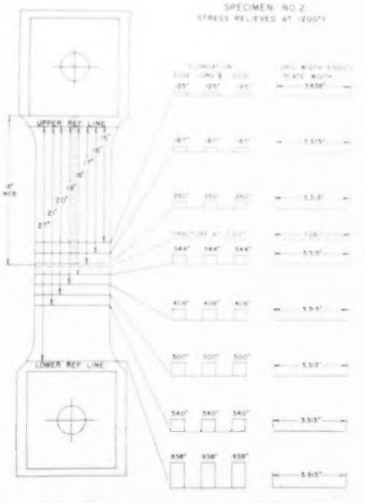



Fig. 15 Elongation chart of Specimen II, stress relieved at 1200° F

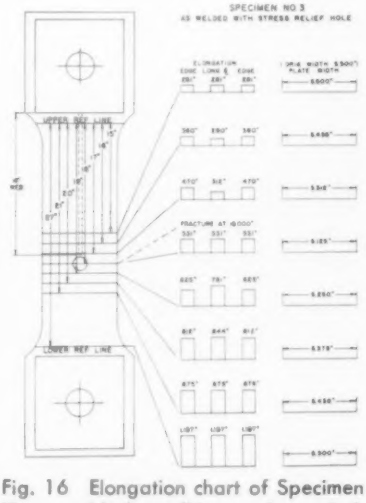



Fig. 16 Elongation chart of Specimen III, as-welded condition and one inch hole at web termination

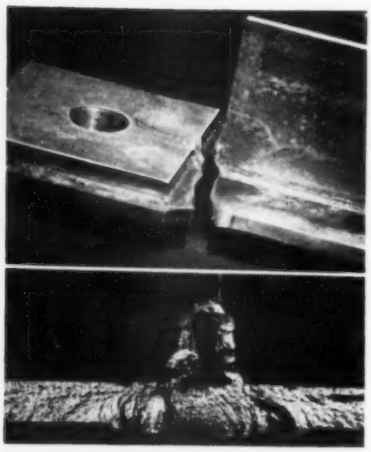


Fig. 17 Example of weld notch trigger in calibration specimen. Tack weld at web end caused fracture

calibration specimen with the result shown in this picture. The area of the specimen in the reduced width equals 2.750 sq in. and the area at actual fracture was 4.000 sq in. The chevron pattern as shown in this figure leaves no room for doubt as to origin of fracture. This unintentional tack weld was also present in the three specimens as presented in this paper. A $^1/_2$-in. hole drilled close as possible to end of web (Fig. 7) stopped the "trigger" action.

***Postheating or Stress Relief by Heat Treatment***

We believe that complete stress relief by heat treatment in a welding composite is a sure way of securing increased ductility, though it would not be the only way.

The impracticability of stress relieving (or postheating) of large weldments is recognized because of problems connected with transfer, furnace limitations and cost.

We believe that by following a similar plan as outlined in our bolster development, satisfactory results can be obtained without resorting to postheating with its attendant burden of added cost.

We expect someday to try preheating the components of large weldments in the material form, prior to welding assembly, as presented by Professor DeGarmo, and we are not in disagreement with his argument.

However, as stated before, this paper is largely a history of experience in a continuing endeavor to improve the product and at the same time to lower cost of production.

# THE ELECTRO-SLAG WELDING PROCESS

*(Continued from page 381-s)*

sion fatigue tests (Table 3) were made at 2200–2400 cpm on specimens 2 x 3 in. cross section, 20 in. long. Peening was performed with a cam-actuated mechanical hammer delivering a 2.2 ft-lb blow 3000 times per minute.

2. "Fatigue Strength of Machined Joints Welded by the Electro-Slag Process," by S. E. Sinadsky and I. N. Gradbov.

The joint to be tested has a cross section of 1.10 x $3^1/_2$ in. A single $^1/_2$-in. electrode, Type Sv-15 G (Table 4) was used. The distance from slag puddle to guide tube was 2.4 in. and the depth of the slag puddle was 2 in. The rate of feed of electrode was 187 ipm. The rate of welding the joint was 0.55 ipm. Current and voltage were 480–500 amp ac, 48–50 v, respectively. The horizontal oscillating speed on the electrode was 18 ipm. Flux FTS-7 was used.

The rotating bend fatigue strength (10 million cycles) of $^3/_4$-in. specimens cut from the normalized weld was 25,000 psi, compared with 23,500 psi for the plate. The welded specimens broke in the base metal or along the fusion line.

3. "Primary Crystallization of Electro-Slag Weld Metal," by V. I. Kotov.

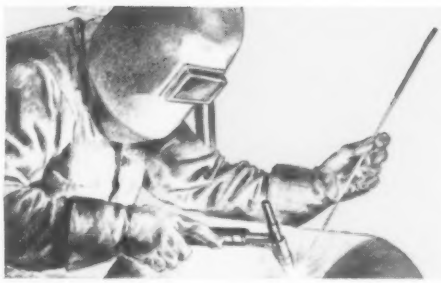
The macrostructure of electro-slag welds consists of two zones, an outer columnar zone and an inner equiaxed zone. Occasionally cracks occur in the inner zone. The chemical composition is the same throughout the cross section of the weld. Tensile and impact specimens were cut from several locations in the welds, which had been heat treated in two ways: (1) Normalized at 1650–1690° F, then drawn at 1200–1240° F; and (2) stress relieved twice at 1200–1240° F. Good properties were obtained in every instance except for a longitudinal impact specimen cut from the center of the weld. This specimen had only 1.6 mkg/cm² compared with 6.7 to 16.1 mkg/cm² for the other specimens.

Table 3—Fatigue Test Results Based on 10 Million Cycles

| *Heat treatment* | *Specimen* | *Fatigue strength, psi* |
|---|---|---|
| As-welded | Plate | 22,000–23,500 |
| As-welded | Weld not machined flush | 12,000 |
| 2 hr at 1200° F | Weld not machined flush | 15,600 |
| 1 hr at 1690° F | Weld not machined flush | 16,400 |
| As-welded | Weld machined flush | 20,000 |
| 2 hr at 1200° F | Weld machined flush | 22,000 |
| 1 hr at 1690° F, then 2 hr at 1200° F | Weld machined flush | 20,000 |
| As-welded | Weld not machined flush but peened | 25,000 |
| As-welded | Weld machined flush and peened | 24,500 |

Table 4—Chemical Composition, %, of Plate, Electrode and Weld

| | *C* | *Mn* | *Si* | *P* | *S* |
|---|---|---|---|---|---|
| Steel 22K, 3.6 in. thick | 0.19 | 0.72 | 0.30 | 0.011 | 0.01 |
| $^1/_2$-in. Sv-15G electrode | 0.16 | 0.93 | Trace | 0.018 | 0.02 |
| Weld metal | 0.17 | 0.62 | 0.22 | 0.021 | 0.02 |



# WELDING ROD CLINIC

J. Imperati and R. F. Pulver, Welding Engineers
The American Brass Company, Waterbury, Conn.

## Steel products are quickly, economically assembled by Braze Welding

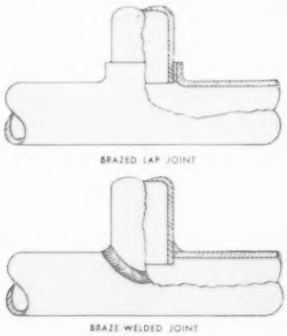
**Velocipede frame** of 2" mild steel tube braze welded with ⅛" Anaconda-997 (Low Fuming) Bronze Welding Rod. The quickest, most dependable and economical method of joining steel tubing says manufacturer, The Frank F. Taylor Co.

Many articles of steel in widespread use are, or can be, economically assembled by oxyacetylene braze welding. Typical of one group are items made of round and square tubing, such as school and office chairs, equipment handles, and frames for bicycles and wheeled toys, portable generator sets, and motor scooters. Another group uses sheet metal, formed moldings, rods, castings, and forgings to make cabinets and enclosures for sinks, refrigerators, files, etc., office furniture, wrought-iron furniture and decorative items, storm sash and screen frames, auto-body parts, and others.

**Advantages.** The advantages of braze welding are fully realized by the use of Anaconda-997 (Low Fuming) Bronze, Tobin Bronze-481 and Nickel Silver-828, because of the low temperature of application, excellent control, and the simplicity of joint and jig design needed for efficient production. Since the low temperatures do not melt the steel, the weld metal is very easily controlled, and there is no need for skilled manipulation of welding rod and flame, as in fusion welding. In addition, there is less tendency to distort the work because of the low temperatures used and the excellent ductility of the weld metal.

**Simple jig design.** In most cases the joints are of such size that they can be made in a single step by heating from one side only. This simplifies jig design and reduces handling operations.

**Savings in joint preparation.** The molten braze-welding alloys easily bridge the gaps resulting from poor fit-up, and readily build up smooth fillets to develop maximum joint strengths. The cost of joint preparation is minimized since there is no need for accurate fit-up.




**Flame fluxing.** A widely used adjunct to braze-welding operations is a vapor-fluxing device, installed in the fuel-gas line, to supply a uniform small amount of flux through the flame. In this way, the joint surfaces are protected from oxidation just as soon as heating is started, and the braze-welding operation is expedited through complete fluxing, increased weld fluidity, less tendency to fume, and elimination of separate fluxing operations.

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**File cabinet panel** of #18 gage mild steel has corners braze welded with Anaconda-997 Rod. Revo-File Co. gets 14 superior welds in 7 minutes.

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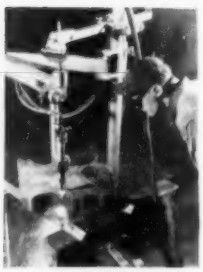
*George W. Rabe, Welding Foreman at Wilmot Engineering Co., says:*

# "When it comes to cutting, our #42 Camograph is a jack-of-all-trades"



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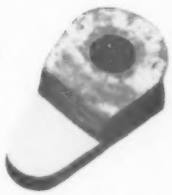
The Airco #42 Camograph shown at left has eliminated much of the manual flame cutting operations in the White Haven, Pa., plant of the Wilmot Engineering Company. Welding Foreman, George W. Rabe, appreciates the way it can be set up, leveled and put to work anywhere in the shop in just a matter of minutes. Accurate Camograph shape cutting reduces the need for machining of many parts including sprockets, lugs and shaft arms. It is often used for moderate production runs of identical pieces.

Learn more about the versatile #42 Camograph and put its many time and labor saving features to work for you. Contact your nearest Airco office or call your local Authorized Airco Dealer for details. Ask for Catalog ADC 853.



**Three cuts by the #42 Camograph eliminated extensive machining to produce this intricate piece.**

*welding*
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